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(54) **SATELLITE AND TERRESTRIAL LOAD BALANCING**

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H04L 12/761 (2013.01)
H04W 88/06 (2009.01)

(52) **U.S. Cl.**

CPC ***H04B 7/18536*** (2013.01); ***H04B 7/18519*** (2013.01); ***H04B 7/18526*** (2013.01); ***H04B 7/18563*** (2013.01); ***H04B 7/18584*** (2013.01); ***H04B 7/18591*** (2013.01); ***H04L 45/16*** (2013.01); *H04W 88/06* (2013.01)

(58) **Field of Classification Search**

CPC H04B 7/18536; H04B 7/18519; H04B 7/18526; H04B 7/18563; H04B 7/18584; H04B 7/18591; H04L 45/16; H04W 88/06

USPC 455/427

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,968,129 A 10/1999 Dillon et al.
9,088,963 B2 7/2015 Ravishankar et al.
10,306,442 B1 * 5/2019 Nuttall H04W 4/70
2011/0280178 A1 * 11/2011 Heifner H04B 7/185 370/325

(Continued)

FOREIGN PATENT DOCUMENTS

EP 1052812 A2 11/2000
EP 1635482 A2 3/2006

OTHER PUBLICATIONS

Invitation to Pay Additional Fees and Annex Communication Relating to the Results of the Partial International Search in PCT/US2019/018650 dated May 13, 2019.

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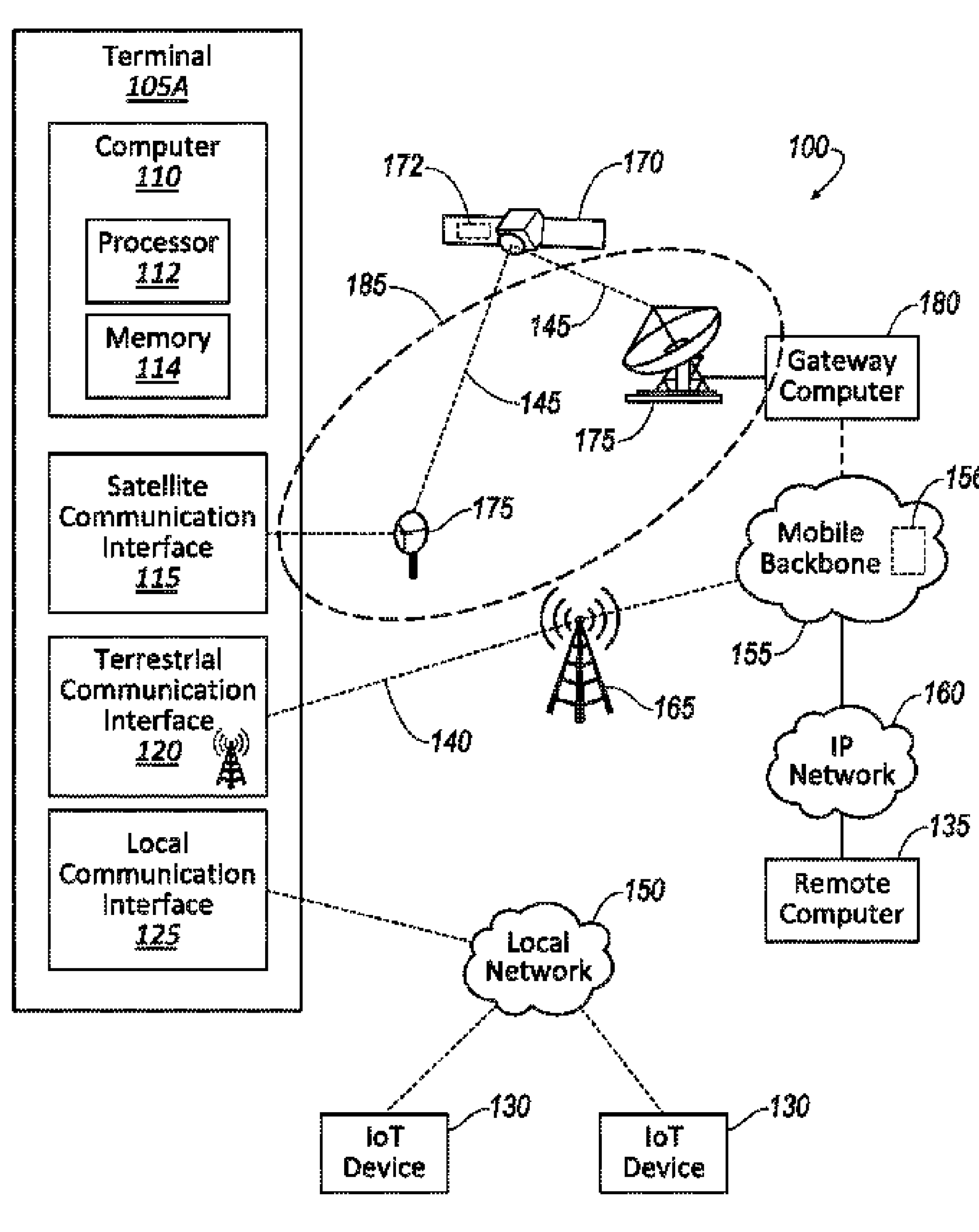
(57) **ABSTRACT**

A system includes a terminal. The terminal includes a terrestrial communication interface, a satellite communication interface and a computer. The terrestrial and satellite communication interfaces are configured to communicate traffic data. The computer is communicatively linked to the terrestrial and satellite communication interfaces. The computer executes instructions comprising, to determine that the traffic data, communicated via the terrestrial communication interface, exceeds a threshold, and based on the determination, to route at least a portion of traffic data via the satellite communication interface in accordance with a predetermined traffic data load-balancing scheme.

18 Claims, 13 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

2013/0121229	A1*	5/2013	Vare	H04H 20/22 370/312
2015/0124616	A1	5/2015	Lohman et al.	
2015/0271730	A1*	9/2015	Benammar	H04W 36/30 455/436
2016/0219024	A1*	7/2016	Verzun	H04L 9/34
2018/0338241	A1*	11/2018	Li	H04L 67/12
2019/0020406	A1*	1/2019	Lindqvist	H01Q 1/1257

* cited by examiner

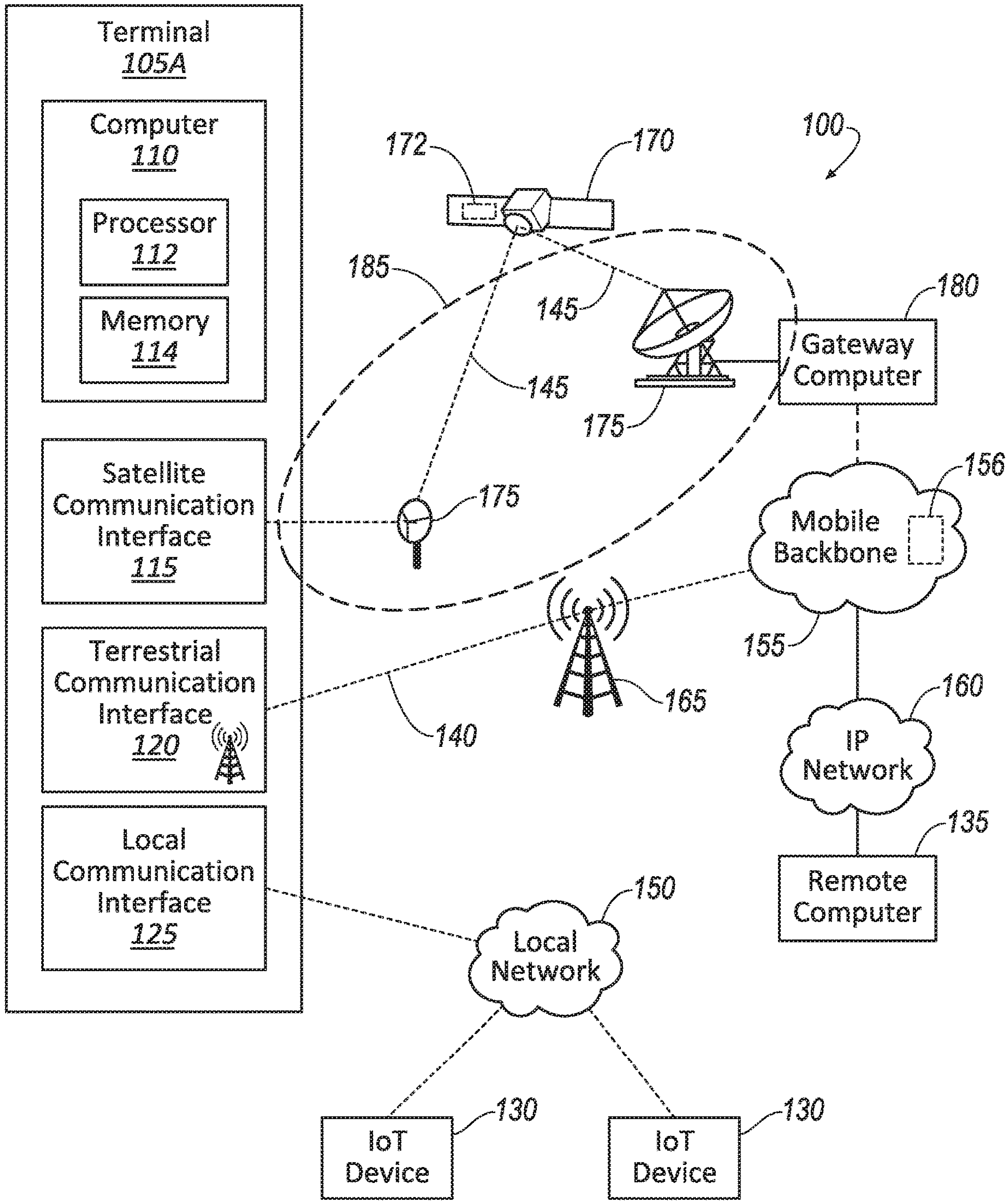

Terminal
105A
Computer
110
Processor
112
Memory
114
Satellite Communication Interface
115
Terrestrial Communication Interface
120
Local Communication Interface
125
172
170
100
185
145
145
175
180
Gateway Computer
175
156
Mobile Backbone
155
165
140
160
IP Network
135
Remote Computer
150
Local Network
130
IoT Device
130
IoT Device

FIG. 1

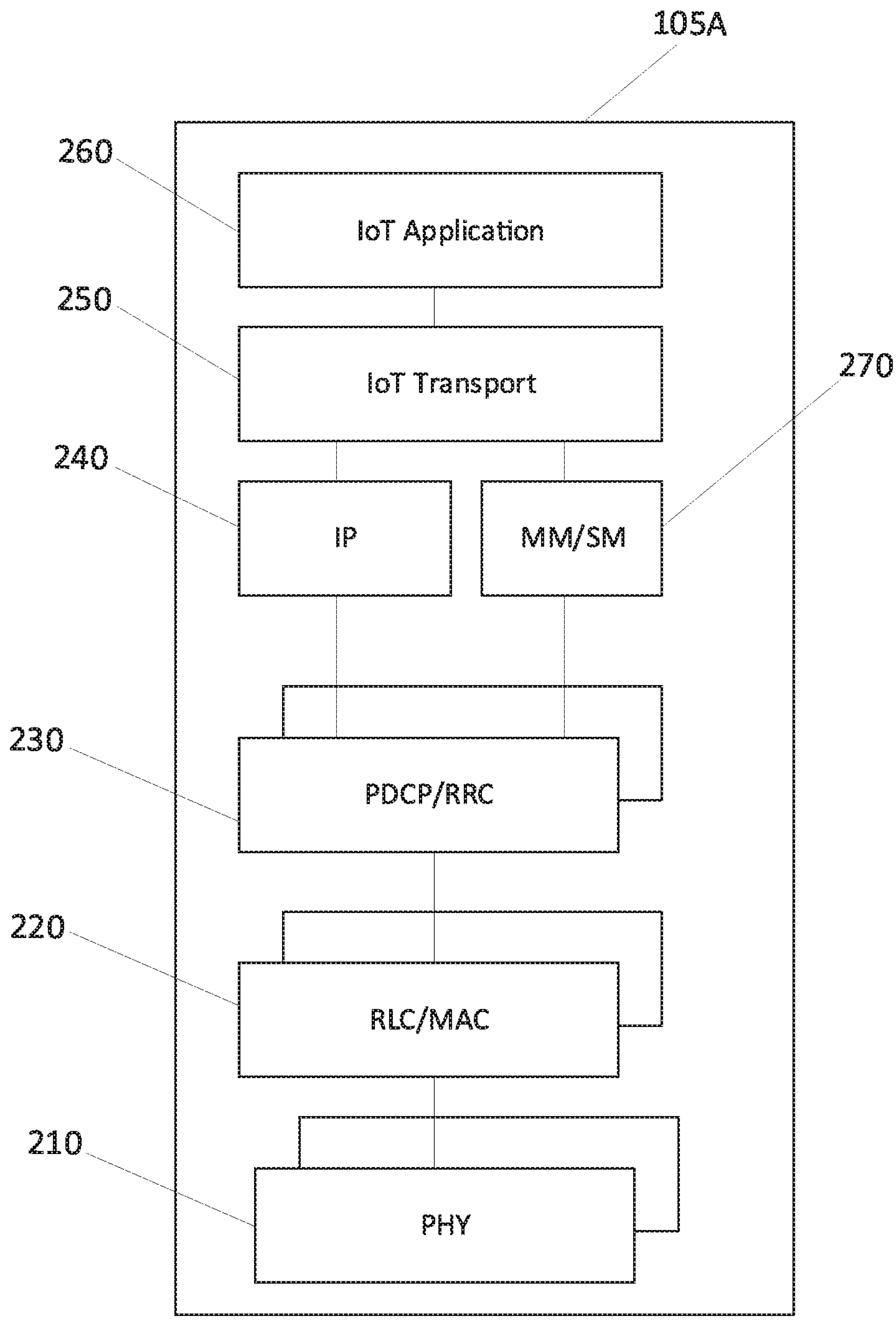

105A
260
IoT Application
250
IoT Transport
270
240
IP
MM/SM
230
PDCP/RRC
220
RLC/MAC
210
PHY

FIG. 2

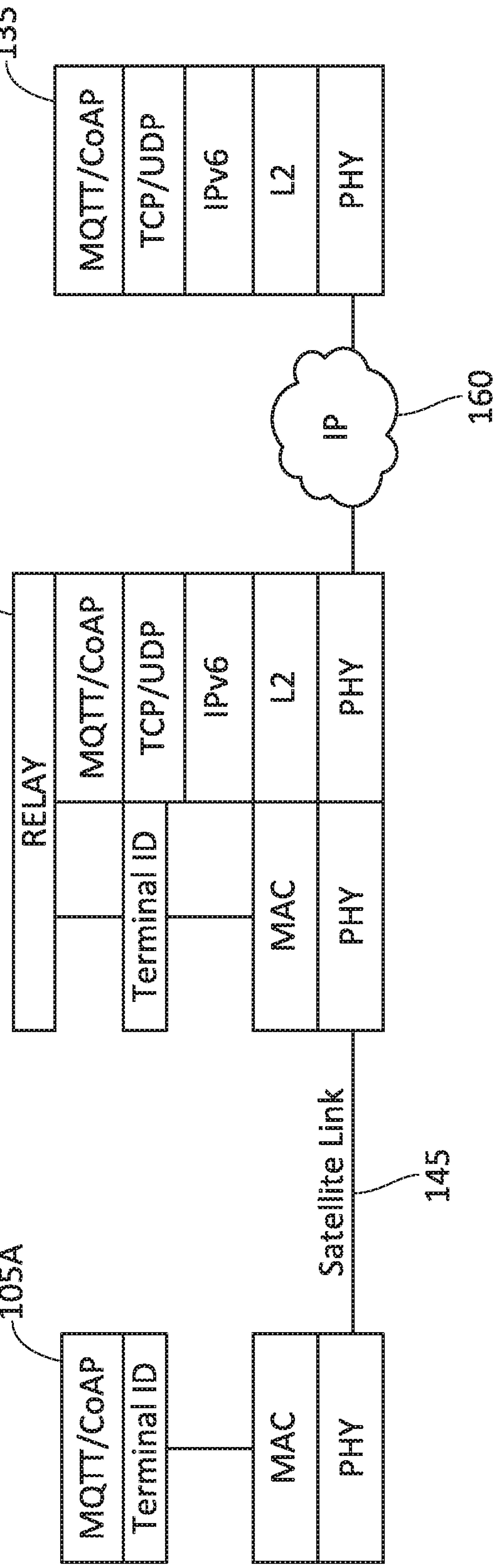

135
MQTT/CoAP
TCP/UDP
IPv6
L2
PHY
IP
160
180
RELAY
MQTT/CoAP
TCP/UDP
IPv6
L2
PHY
Terminal ID
MAC
PHY
Satellite Link
145
105A
MQTT/CoAP
Terminal ID
MAC
PHY

FIG. 3

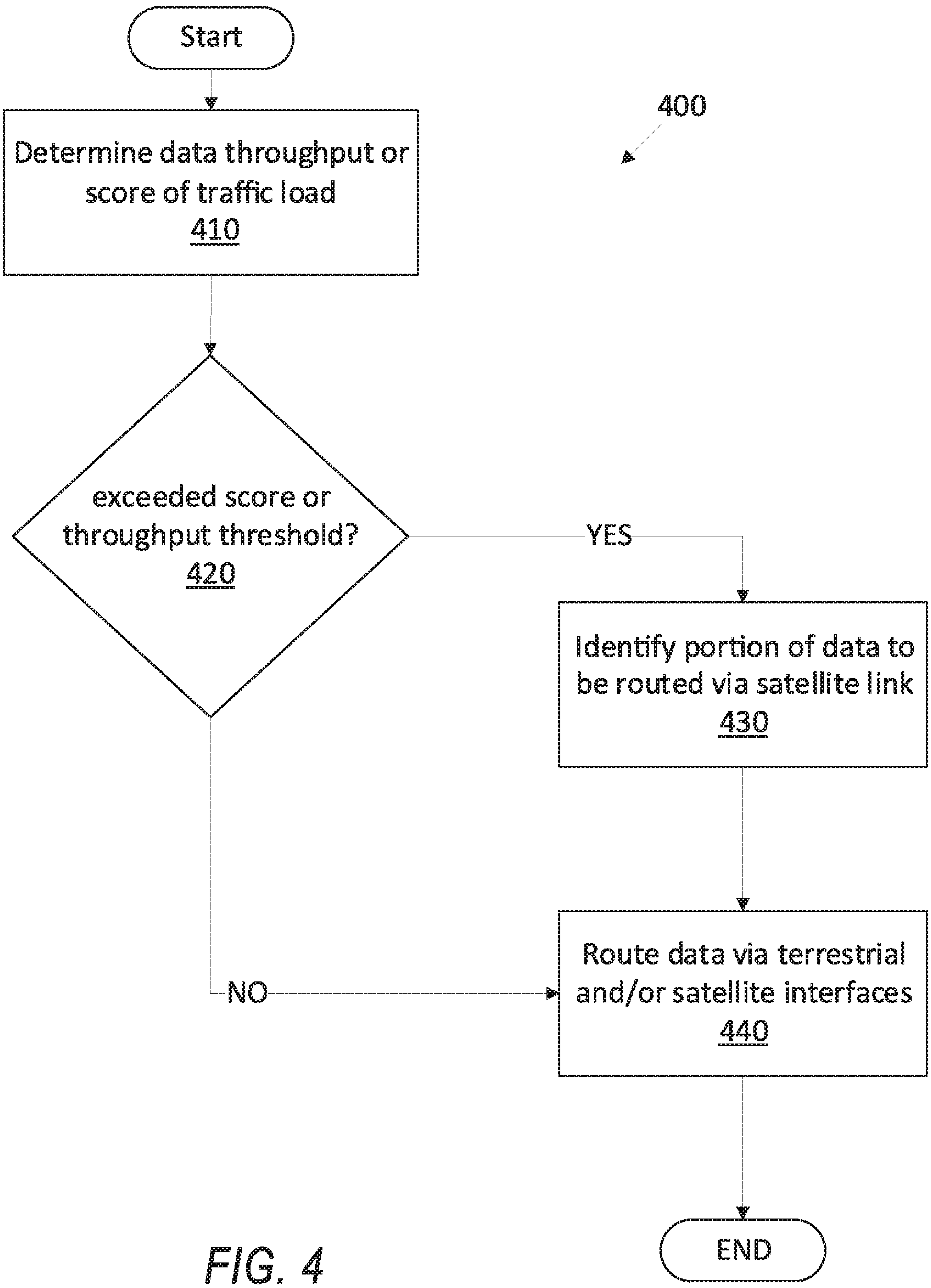

Start
Determine data throughput or score of traffic load
410
400
exceeded score or throughput threshold?
420
YES
NO
Identify portion of data to be routed via satellite link
430
Route data via terrestrial and/or satellite interfaces
440
END

FIG. 4

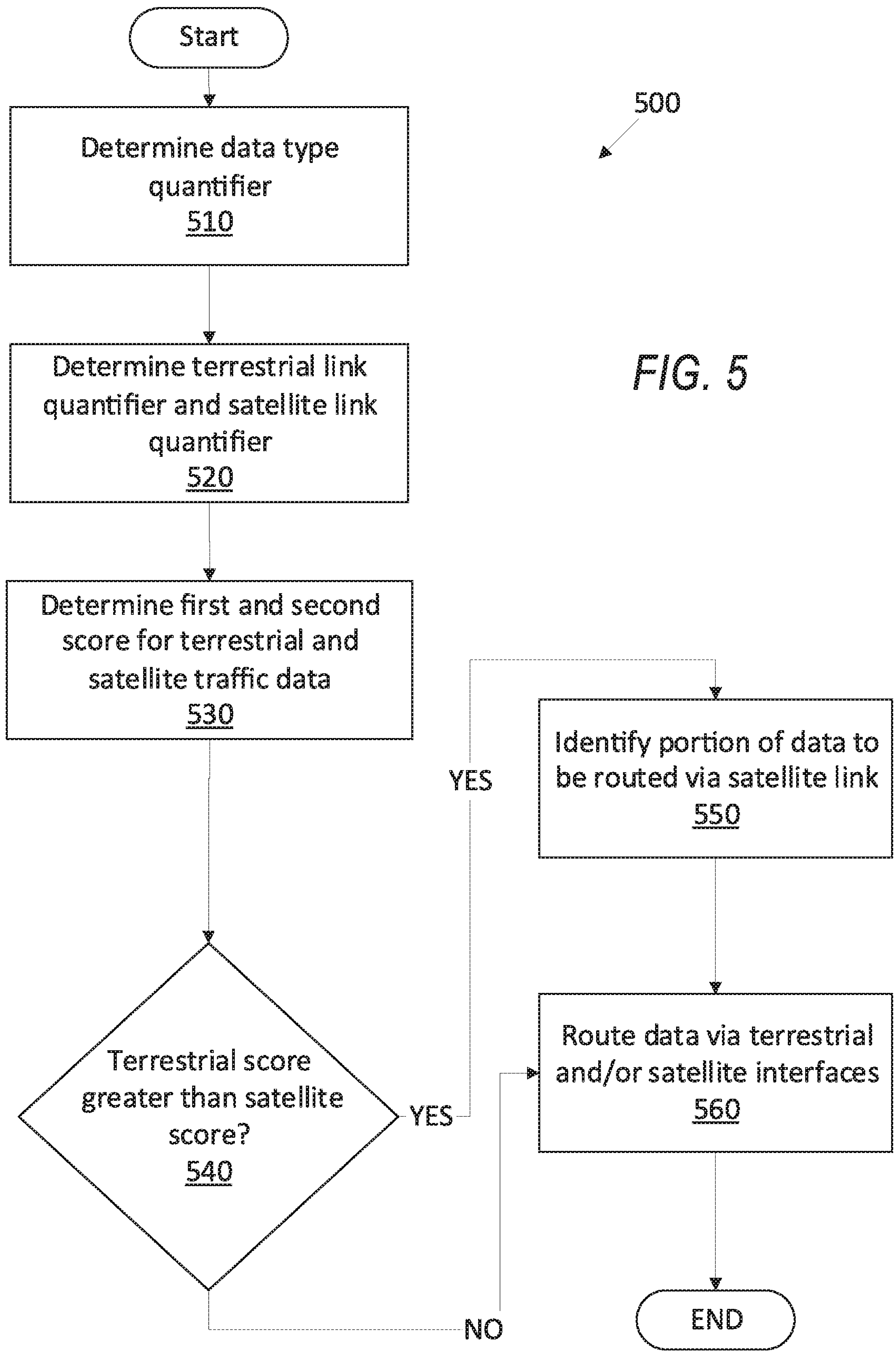

Start
500
Determine data type quantifier
510
Determine terrestrial link quantifier and satellite link quantifier
520
Determine first and second score for terrestrial and satellite traffic data
530
Terrestrial score greater than satellite score?
540
YES
YES
NO
Identify portion of data to be routed via satellite link
550
Route data via terrestrial and/or satellite interfaces
560
END

FIG. 5

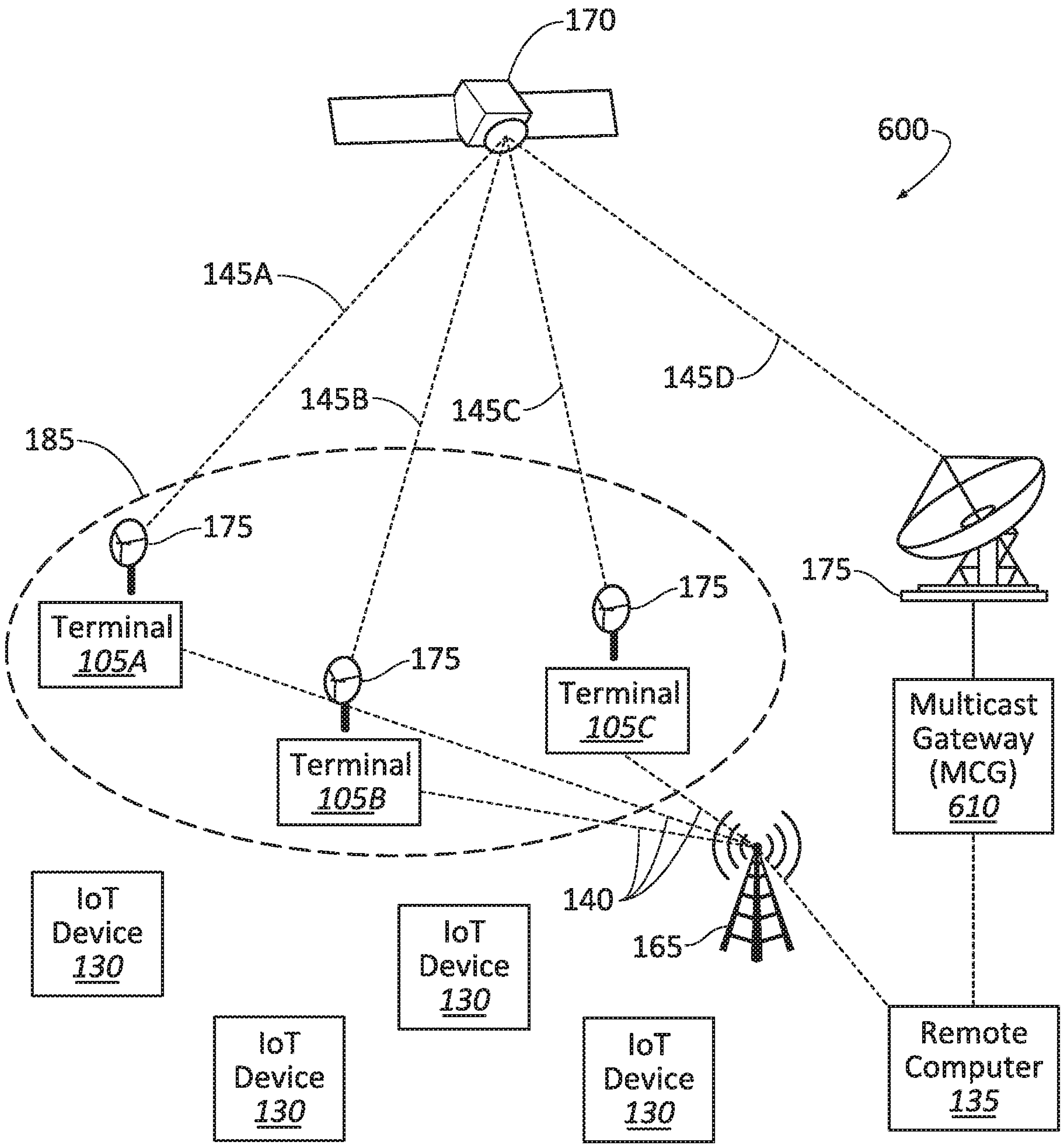

170
600
145A
145B
145C
145D
185
175
Terminal
105A
175
Terminal
105B
175
Terminal
105C
175
Multicast
Gateway
(MCG)
610
140
165
IoT
Device
130
IoT
Device
130
IoT
Device
130
IoT
Device
130
Remote
Computer
135

FIG. 6

FIG. 7

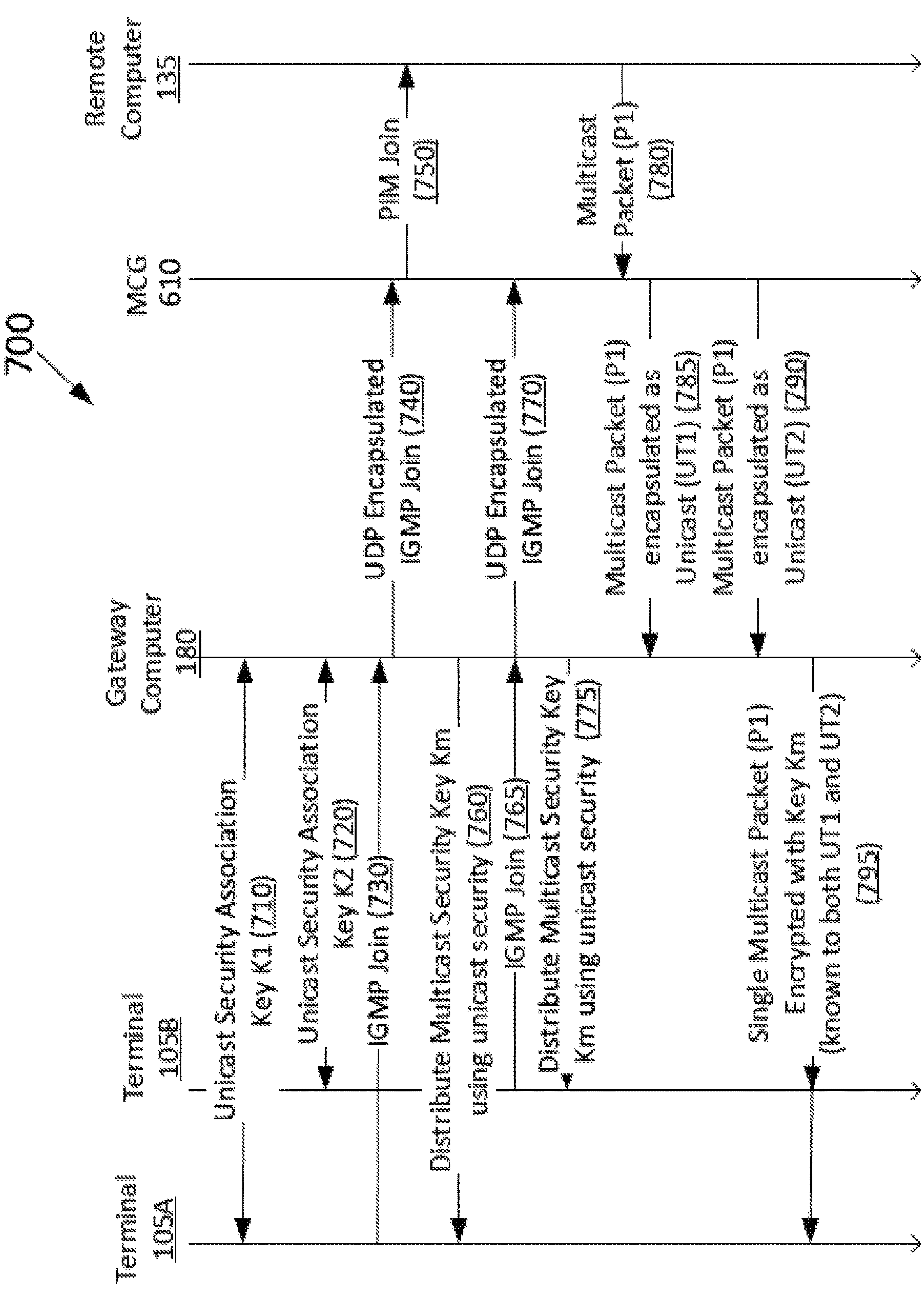
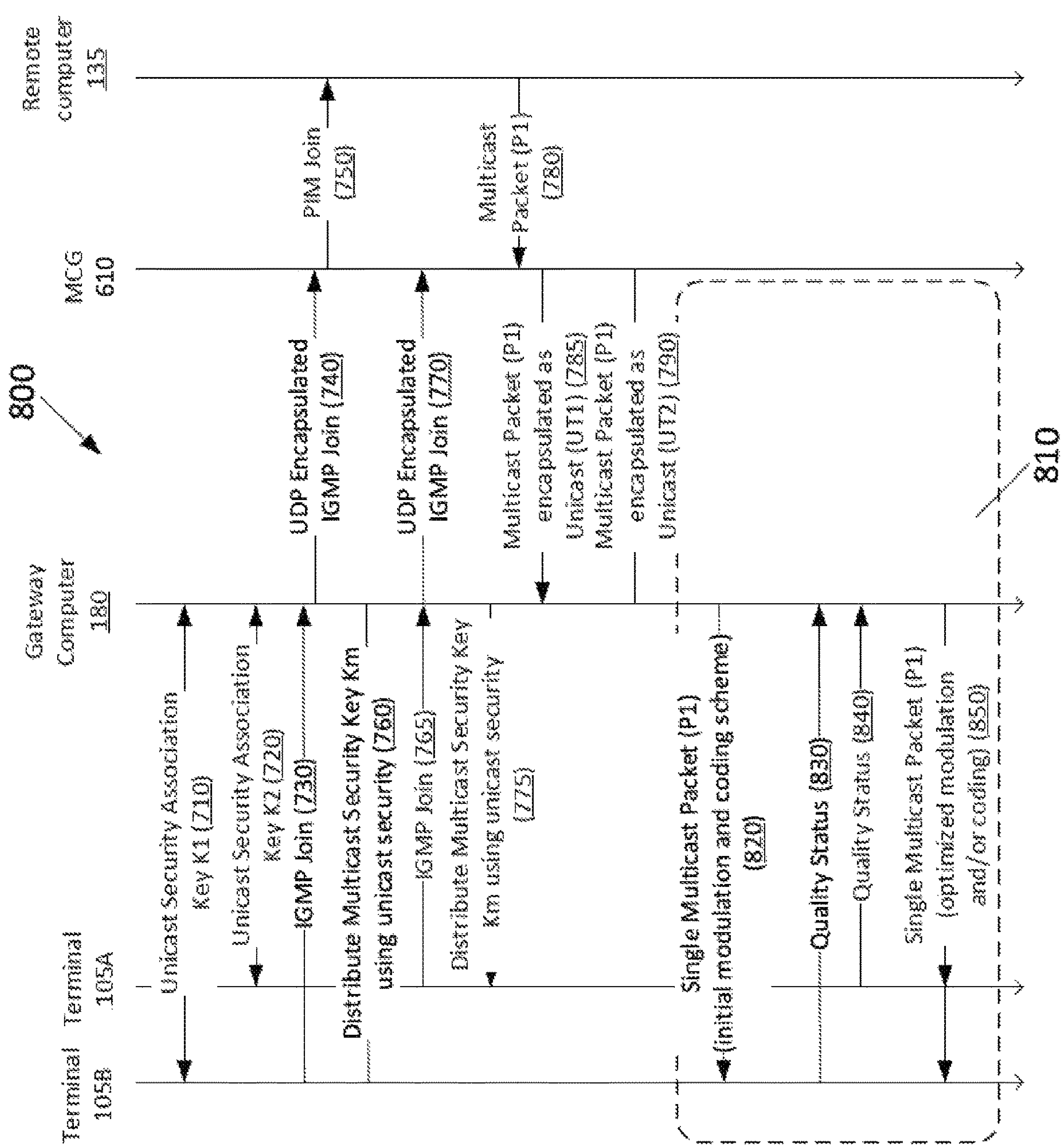

700
Terminal 105A
Terminal 105B
Gateway Computer 180
MCG 610
Remote Computer 135
Unicast Security Association Key K1 (710)
Unicast Security Association Key K2 (720)
IGMP Join (730)
UDP Encapsulated IGMP Join (740)
PIM Join (750)
Distribute Multicast Security Key Km using unicast security (760)
IGMP Join (765)
UDP Encapsulated IGMP Join (770)
Distribute Multicast Security Key Km using unicast security (775)
Multicast Packet (P1) (780)
Multicast Packet (P1) encapsulated as Unicast (UT1) (785)
Multicast Packet (P1) encapsulated as Unicast (UT2) (790)
Single Multicast Packet (P1) Encrypted with Key Km (known to both UT1 and UT2) (795)

FIG. 8



800
Terminal 105B
Terminal 105A
Gateway Computer 180
MCG 610
Remote computer 135
Unicast Security Association Key K1 (710)
Unicast Security Association Key K2 (720)
IGMP Join (730)
UDP Encapsulated IGMP Join (740)
PIM Join (750)
Distribute Multicast Security Key Km using unicast security (760)
IGMP Join (765)
UDP Encapsulated IGMP Join (770)
Distribute Multicast Security Key Km using unicast security (775)
Multicast Packet (P1) (780)
Multicast Packet (P1) encapsulated as Unicast (UT1) (785)
Multicast Packet (P1) encapsulated as Unicast (UT2) (790)
Single Multicast Packet (P1) (initial modulation and coding scheme) (820)
Quality Status (830)
Quality Status (840)
Single Multicast Packet (P1) (optimized modulation and/or coding) (850)
810

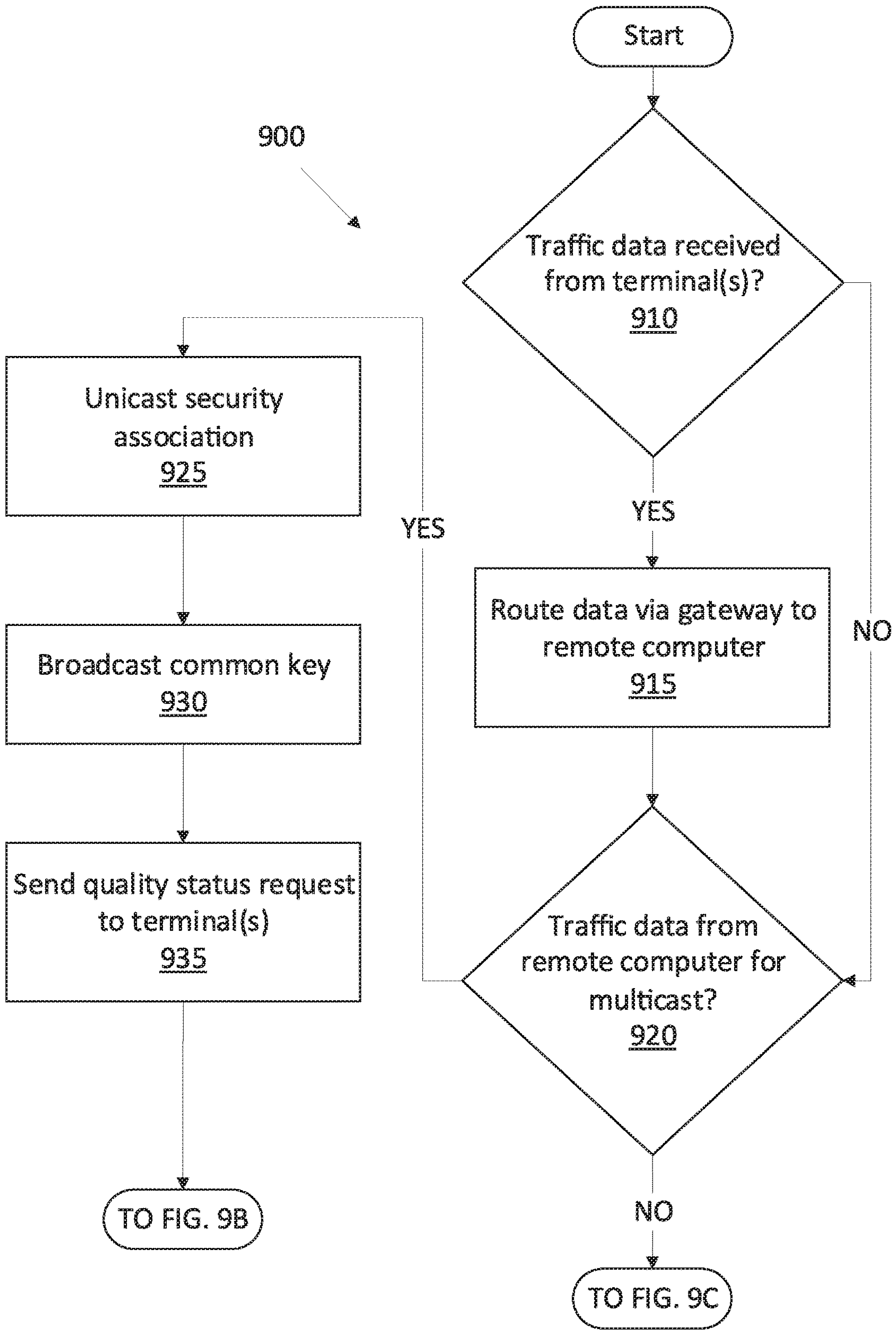

Start
900
Traffic data received from terminal(s)?
910
YES
NO
Route data via gateway to remote computer
915
Traffic data from remote computer for multicast?
920
YES
NO
TO FIG. 9C
Unicast security association
925
Broadcast common key
930
Send quality status request to terminal(s)
935
TO FIG. 9B

FIG. 9A

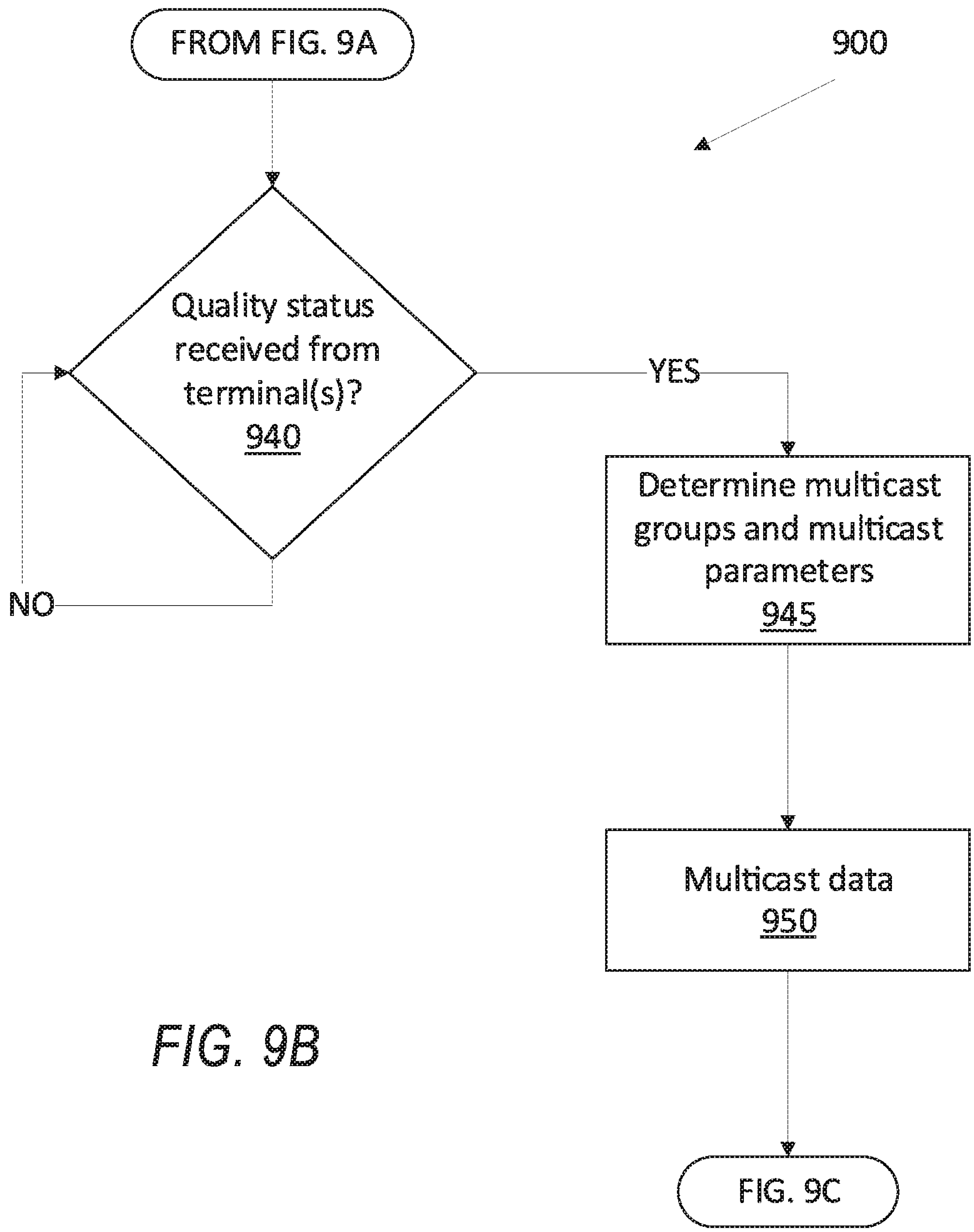

FROM FIG. 9A
900
Quality status received from terminal(s)? 940
YES
NO
Determine multicast groups and multicast parameters 945
Multicast data 950
FIG. 9C

FIG. 9B

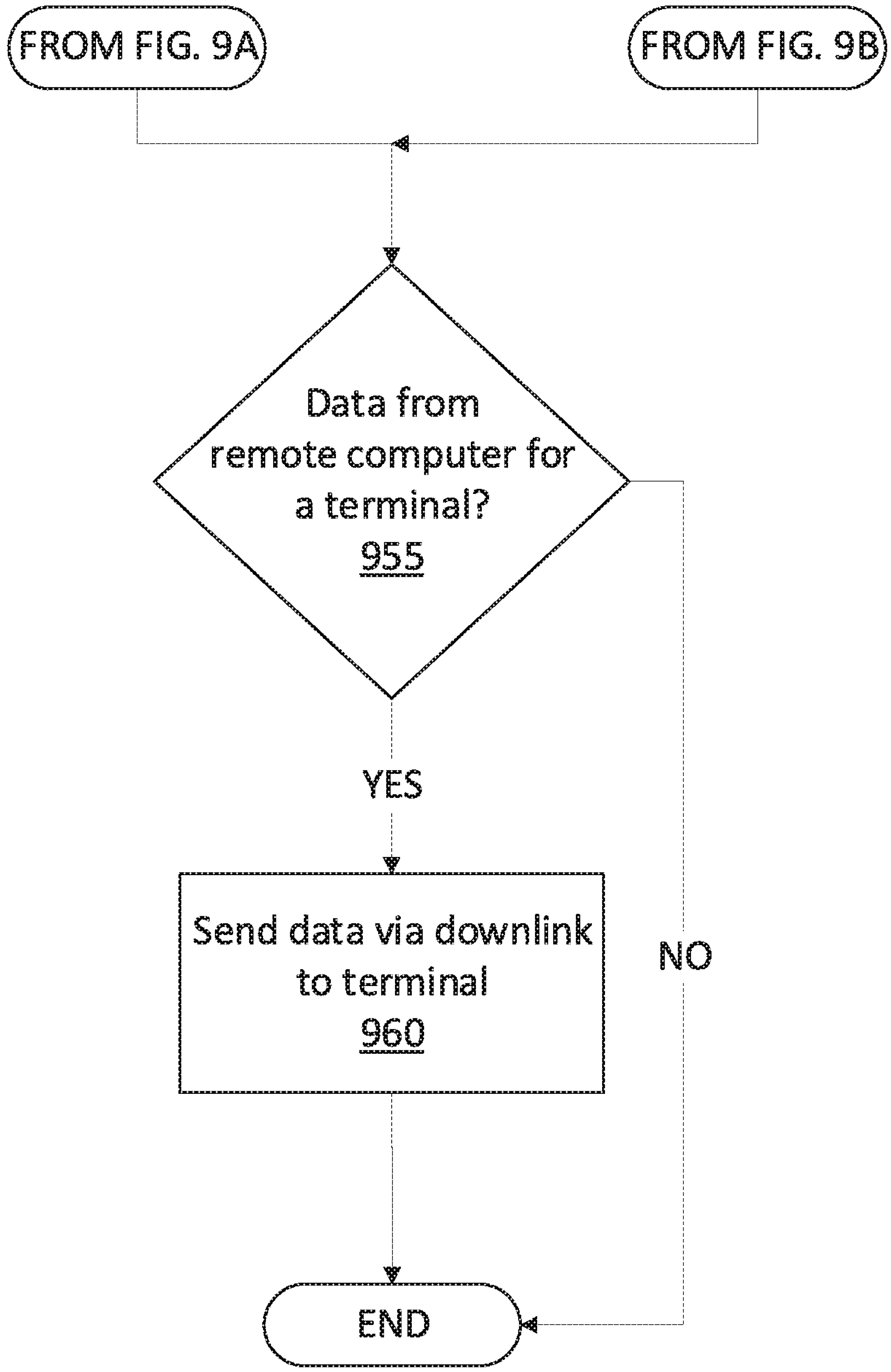

FROM FIG. 9A
FROM FIG. 9B
Data from remote computer for a terminal?
955
YES
Send data via downlink to terminal
960
NO
END

FIG. 9C

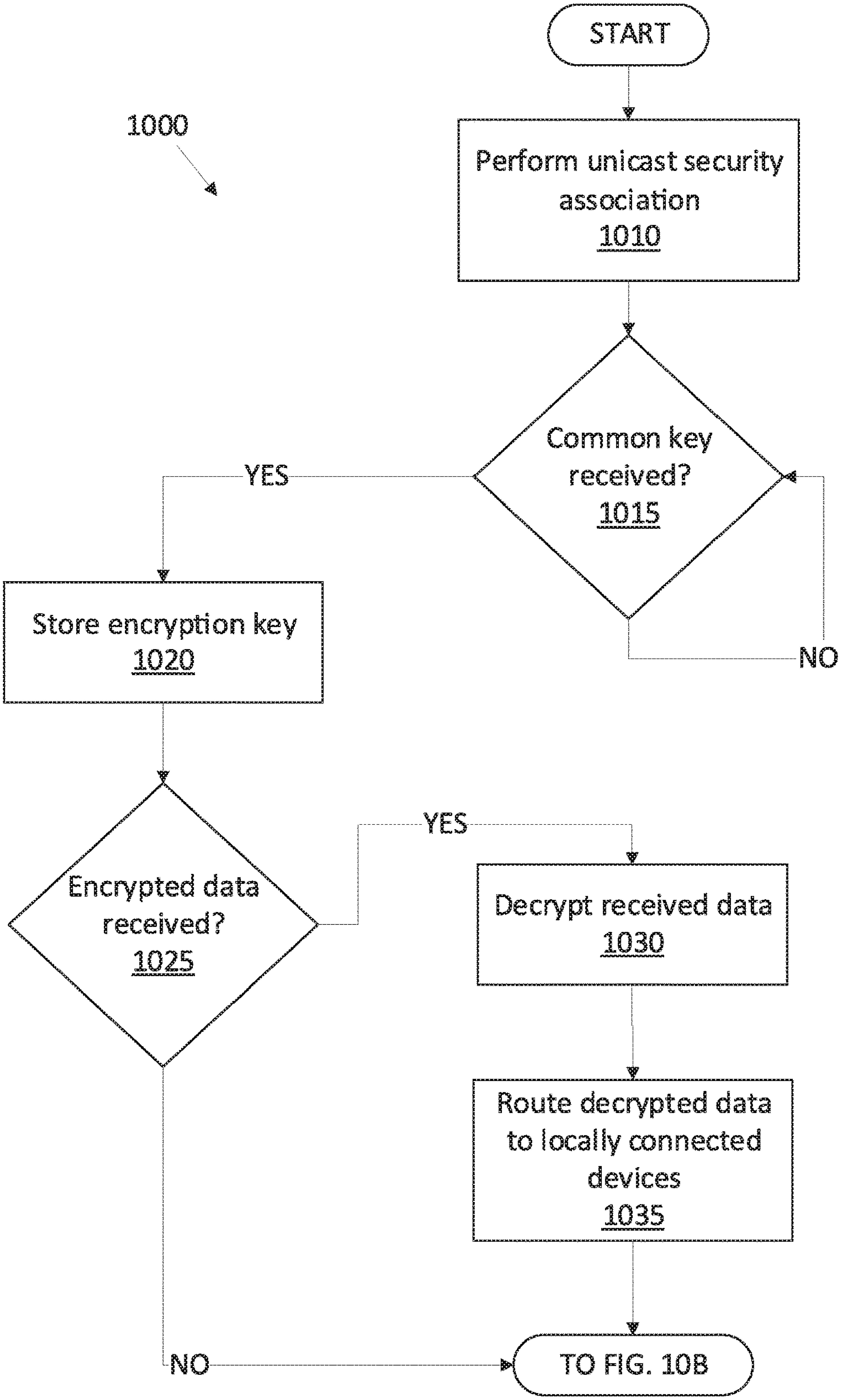

START
1000
Perform unicast security association
1010
Common key received?
1015
YES
NO
Store encryption key
1020
Encrypted data received?
1025
YES
Decrypt received data
1030
Route decrypted data to locally connected devices
1035
NO
TO FIG. 10B

FIG. 10A

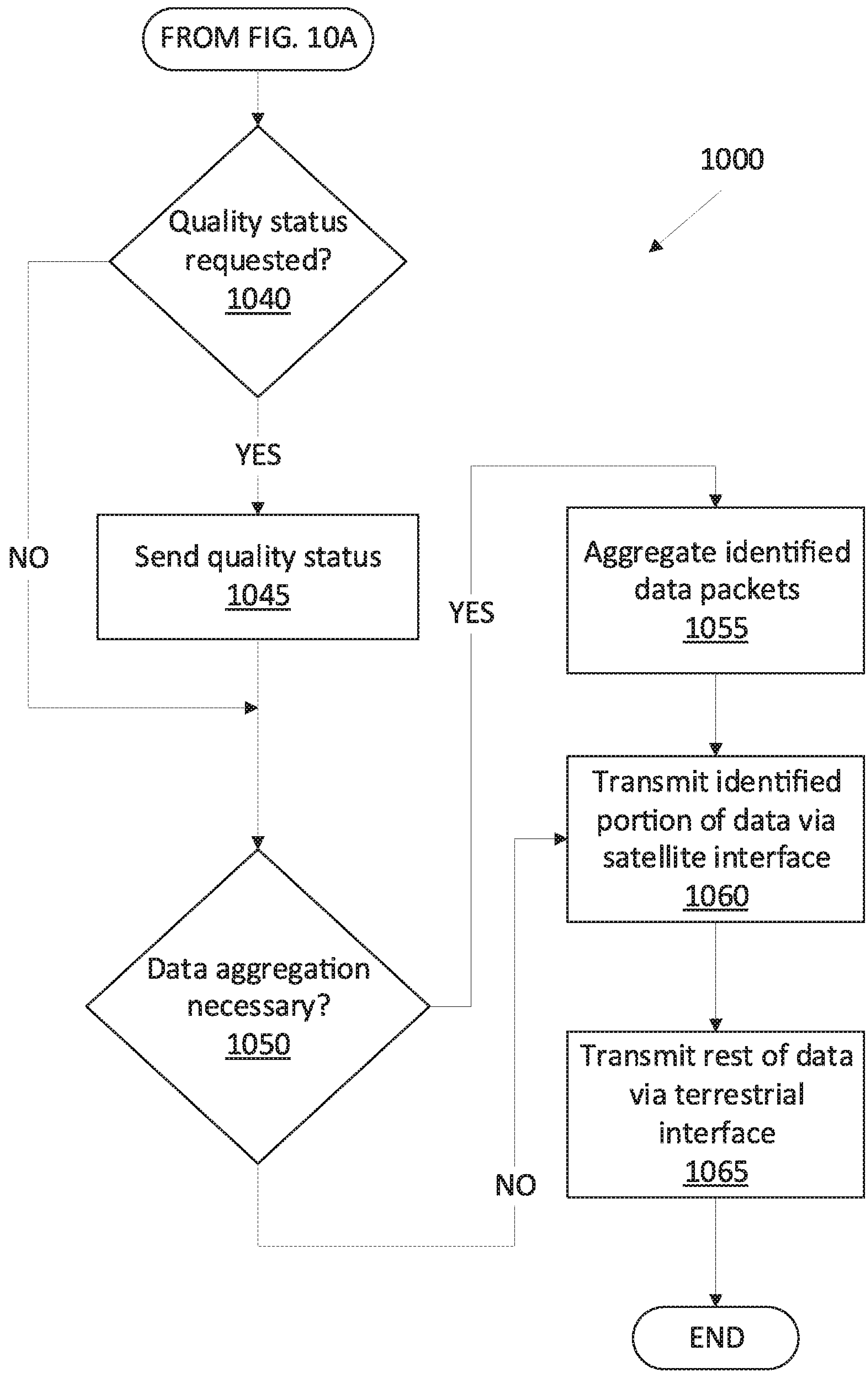

FROM FIG. 10A
1000
Quality status requested?
1040
YES
NO
Send quality status
1045
YES
Aggregate identified data packets
1055
Transmit identified portion of data via satellite interface
1060
Data aggregation necessary?
1050
Transmit rest of data via terrestrial interface
1065
NO
END

FIG. 10B

SATELLITE AND TERRESTRIAL LOAD BALANCING

CROSS-REFERENCE TO RELATED APPLICATIONS

This patent application claims priority to and all the benefits of U.S. Provisional Patent Application No. 62/632,643 filed on Feb. 20, 2018, which is herein incorporated by reference in its entirety

BACKGROUND

Terrestrial communication is utilized as a wireless communication technology, e.g., for communication of IoT (Internet of Things) devices to a remote server, etc. IoT devices such as sensors, actuators, smart devices, etc., may be deployed in various geographical areas. The IoT devices typically send data to a remote computer, e.g., an IoT server, and/or receive data from the remote computer. A congestion of a wireless network such as a terrestrial communication network and/or inadequate coverage of a location, e.g., unserved or underserved remote areas, may impact an operation of IoT devices.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates an example communication network with a hybrid satellite terminal communicating via terrestrial and satellite communication networks.

FIG. **2** is an example software architecture of the hybrid satellite terminal of FIG. **1**.

FIG. **3** is an example software architecture illustrating an operation of the gateway of FIG. **1**.

FIG. **4** is a flowchart of a first example process for balancing traffic data between terrestrial and satellite communication networks.

FIG. **5** is a flowchart of a second example process for balancing traffic data between terrestrial and satellite communication networks.

FIG. **6** is an example communication network for multicasting data to a plurality of IoT devices.

FIG. **7** is an example sequence diagram for multicasting encrypted data to a plurality of terminals.

FIG. **8** is an example sequence diagram for adapting satellite downlink(s) for multicasting data to a plurality of terminal with different reception characteristics.

FIGS. **9**A-**9**C are an example flowchart for operating a satellite or a satellite gateway.

FIGS. **10**A-**10**B are an example flowchart for routing data via terrestrial and satellite interfaces of a satellite terminal.

DETAILED DESCRIPTION

Introduction

Disclosed herein is a system comprising a terminal. The terminal includes a terrestrial communication interface, a satellite communication interface, and a computer. The terrestrial and satellite communication interfaces are configured to communicate traffic data. The computer is communicatively linked to the terrestrial and satellite communication interfaces, and the executes instructions comprising, to determine that the traffic data, communicated via the terrestrial communication interface, exceeds a threshold, and based on the determination, route at least a

portion of traffic data via the satellite communication interface in accordance with a predetermined traffic data load-balancing scheme.

The computer may be further programmed to determine a terrestrial link quantifier and a satellite link quantifier, and select at least one of the terrestrial communication interface and the satellite communication interface further based on the terrestrial link quantifier and the satellite link quantifier.

The computer may be further programmed to determine a first score of the traffic data based on at least one of a data throughput, a data type quantifier, and a terrestrial link quantifier, and to route at least the portion of traffic data via the satellite communication interface upon determining that the first score of the traffic data exceeds the threshold.

The computer may be further programmed to determine the data type quantifier based at least on one of the data throughput, a data volume, and a data priority.

The computer may be further programmed to determine the data priority based at least in part on a latency threshold of the traffic data.

The computer may be further programmed to receive, via a local communication network, a plurality of data packets from a plurality of IoT devices, generate an aggregated data packet including the received plurality of data packets, and transmit the aggregated data packet via the satellite communication interface to the remote computer.

The computer may be further programmed to determine a first score of the plurality of data packets for communicating via the terrestrial communication interface, to determine a second score of the aggregated data packet for communicating via the satellite communication interface, and to transmit the aggregated data packet via the satellite communication interface upon determining that first score exceeds the second score.

The computer may be further programmed to communicate with one or more IoT devices, via an IoT interface, wherein the traffic data includes data received from or sent to the one or more IoT devices.

The system may further include a gateway computer, programmed to receive data from remote computer, and to multicast the received remote computer data to a plurality of terminals, wherein the plurality of terminals communicates with IoT devices via one or more local communication network.

The gateway computer may be further programmed to distribute an encryption key, in a unicast mode, to the plurality of second computers, to encrypt the received remote computer data with the key, and to multicast the encrypted remote computer data to the plurality of terminals.

The system may further include an IoT device comprising a second computer, programmed to receive the distributed key and the encrypted multicast data, to decrypt the multicast data based on the distributed key, and to actuate an actuator based on the decrypted data.

The gateway computer may be further programmed to receive, via a satellite uplink, a reception quality status including a link condition, and to adjust, based on the received quality status, at least one of multicast parameters including a data throughput, a transmission power, and a transmission spectral efficiency.

The gateway computer may be further programmed to divide, based on the received quality status, the plurality of terminals into a first group with a first set of multicast parameters and a second group with a second set of multicast parameters, to multicast the remote computer data based on the first set of multicast parameters via a first downlink, and to multicast the remote computer data based on the second set of multicast parameters via a second downlink.

Further disclosed herein is a system, comprising a gateway computer, programmed to receive data from a remote computer, to multicast the received data to a plurality of terminals, communicatively connected to IoT devices via one or more local communication networks, to receive, via a satellite uplink, a reception quality status from the plurality of terminals, wherein the reception quality status includes a link condition, and to adjust, based on the received quality status, at least one of multicast parameters including a data throughput, a transmission power, and a transmission spectral efficiency.

The gateway computer may be further programmed to divide, based on the received quality status, the plurality of terminals into a first group with a first set of multicast parameters and a second group with a second set of multicast parameters, to multicast the remote computer data based on the first set of multicast parameters via a first downlink, and to multicast the remote computer data based on the second set of multicast parameters via a second downlink.

Further disclosed herein is a method, comprising determining that traffic data of a terminal, communicated via a terrestrial communication interface of the terminal, exceeds a threshold, and based on the determination, routing at least a portion of traffic data via a satellite communication interface of the terminal in accordance with a predetermined traffic data load-balancing scheme, wherein the terrestrial and satellite communication interfaces are configured to communicate traffic data.

The method may further include determining a terrestrial link quantifier and a satellite link quantifier, and selecting at least one of the terrestrial communication interface and the satellite communication interface further based on the terrestrial link quantifier and the satellite link quantifier.

The method may further include determining a score of the traffic data based on at least one of a data throughput, a data type quantifier, and a terrestrial link quantifier, and routing at least the portion of traffic data via the satellite communication interface upon determining that the score of the traffic data exceeds the threshold.

The method may further include determining the data type quantifier based at least on one of the data throughput, a data volume, and a data priority.

The method may further include determining the data priority based at least in part on a latency threshold of the traffic data.

Further disclosed is a computing device programmed to execute the any of the above method steps.

Yet further disclosed is a computer program product comprising a computer readable medium storing instructions executable by a computer processor, to execute the any of the above method steps.

Exemplary System Elements

Operation of distributed systems such as IoT devices communicating with remote computers rely on wired and/or wireless communication networks which provide data communication between various parts of the system, e.g., IoT devices and IoT servers. However, a wireless communication network, e.g., a terrestrial wireless communication network, may fail to provide an efficient, reliable, and/or cost-effective path for communicating traffic data in a distributed system. This disclosure pertains to systems and methods to identify such conditions and improve wireless data communication in a distributed system.

Non-limiting examples of such a system may include a satellite terminal system having a terrestrial communication interface, a satellite communication interface, and a computer. The terrestrial and satellite communication interfaces can be configured to communicate traffic data (e.g., data exchanged between the IoT devices and IoT servers). The satellite terminal system can further include a computer communicatively linked to the terrestrial and satellite communication interfaces. The computer may be programmed to determine that the traffic data, communicated via the terrestrial communication interface, exceeds a threshold, and based on the determination, route at least a portion of traffic data via the satellite communication interface in accordance with a predetermined traffic data load-balancing scheme. Non-limiting examples of such a system may include a satellite computer that is programmed to receive, via a satellite uplink, terminal data from a satellite terminal on the ground, and multicast, via a downlink, the received terminal data, to a plurality of IoT devices.

FIG. **1** illustrates a block diagram of an example distributed system **100** including satellite terminal(s) **105**A, IoT devices **130**, and remote computer(s) **135**, communicating via a combination of terrestrial communication link(s) **140**, satellite communication links **145**, local communication network(s) **150**, a mobile communication network such as 5G Core mobile backbone **155**, and/or an IP (Internet Protocol) network **160**. In the illustration, only one satellite terminal **105**A is shown for purposes of illustration; however, it should be appreciated that any suitable quantity of satellite terminals **105**A may be used instead. In another example embodiment, one or more IoT devices **130** may be included in the terminal **105**A. In other words, the terminal **105**A may additionally provide IoT device **130** operation.

Distributed network **100** is a network of computers located in a geographical area, e.g., a building, a neighborhood, a city, a country, etc., that exchange data via a combination of wired and/or wireless communication networks. The distributed network **100** may include a variety of different types of communication networks such as terrestrial, satellite, local communication networks, etc., as discussed below. Internet of Things (IoT) is an example of a distributed network **100** including devices **130** such as smart devices, sensors, actuators, vehicles, etc. and remote computers **135** (sometimes referred to as IoT servers) that are connected wired and/or wirelessly to exchange data. In the present context, a remote computer **135** may be programmed to communicate with a plurality, e.g., thousands, of IoT devices **130**, e.g., to transmit actuation instructions to an actuator IoT device **130**, receive data from a sensor device **130**, and/or update programming of an IoT device **130** such as a thermostat, etc. In the present context, a remote computer **135** may include multiple remote computers **135**. In other words, not all programming of computer **135** discussed herein is necessarily implemented in one remote computer **135**.

A communication network may be one or more of various wired or wireless communication mechanisms, including any desired combination of wired (e.g., cable and fiber) and/or wireless (e.g., cellular, wireless, satellite, microwave and radio frequency) communication mechanisms and any desired network topology (or topologies when multiple communication mechanisms are utilized). Exemplary communication networks include wireless communication networks (e.g., using one or more of cellular, Bluetooth, IEEE 802.11, etc.), local area networks (LAN) and/or wide area networks (WAN), including the Internet, providing data communication services.

A terrestrial communication system, e.g., LTE (Long-Term Evolution), 5G, etc. may include a mobile network backbone **155** and a plurality of base stations **165**. The base stations **165** may be connected to the backbone **155** via a wired and/or wireless network. The base stations **165** provide a terrestrial communication link **140**, e.g., 5G, LTE, etc., to the terminal **105**A. The backbone **155** of the terrestrial communication system may be connected to an IP network **160**, e.g., to provide access to the remote computer **135** via internet. A terrestrial communication link **140** is established when a wireless communication, e.g., via LTE protocol, is initiated between terminal **105**A and a base station **165**.

An IP (Internet Protocol) network **160** has a task of delivering data packets from a source host to a destination host solely based on an IP addresses in the packet headers. For this purpose, IP defines packet structures that encapsulate the data to be delivered. It also defines addressing methods that are used to label the datagram with source and destination information.

IoT devices **130** may be implemented by chips, circuits, electromechanical components, etc. IoT devices **130** typically include a communication interface, e.g., WiFi, Bluetooth, LAN (Local Area Network), etc., to communicate, e.g., via the terminal **105**A, links **140**, **145**, etc., with a remote computer. An IoT device **130** may include a sensor such as temperature, pressure, etc. sensor and an IoT device **130** processor may be programmed to receive data from the sensor and send the received data via the IoT **130** interface to a remote computer. As another example, an IoT device **130** may include an actuator, e.g., an alarm, a relay, a hydraulic component, etc. and the IoT device **130** processor may be programmed to receive data from a remote computer and actuate the IoT device **130** actuator based on the received data. As another example, an IoT device **130** may be a thermostat, a programmable control unit, etc. The IoT devices **130** may be connected to the terminal(s) **105**A via a local communication network **150**. The local communication network **150** may be an IP-based network such as an IEEE 802.15.4, low power Wi-Fi, 6LoWPAN (IP version 6 over Low-Power Wireless Personal Area Networks), etc. Additionally, or alternatively, a local communication network **150** may be a non-IP based network such as NFC (Near-Field Communication), LoRa™ (Long Range), BLE (Bluetooth Low Energy), Zigbee, etc.

The system **100** may include satellite(s) **170** that provide wireless communication via the satellite links **145** to one or more terminals **105**A which are within a coverage area **185** of the satellite **170**. In the present context, a satellite link **145** is a wireless communication between a dish **175** antenna and a satellite **170** antenna. A satellite link **145** may include an uplink, including communication from terminal **105**A to a satellite **170**, a gateway **180**, etc. and/or a downlink, which includes communication from the satellite **170** to the terminal **105**A, gateway **180**, etc.

Satellite **170** may include a computer **172** having a processor and a memory storing instructions to operate the satellite **170**, e.g., including providing configuring links **145** (uplink and/or downlink), receiving and/or transmitting data, etc. In another example, the satellite **170** may include a bent-pipe implementation that forwards the received information without any data processing. In the present context, a coverage area **185** of a satellite **170** is a geographical area on the surface of Earth, in which terminal **105**A, gateway **180**, etc., may communicate with the satellite **170**. In one example, a coverage area **185** may be an area, e.g., a city, etc., covered with a spot beam. In yet another example, a coverage area **185** may be an area covered by a gateway beam, i.e., available for communication with a gateway **180** on Earth. Other parameters such as weather conditions, objects such as buildings, trees, etc., may affect a coverage area, e.g., reduce the coverage area **185**. A shape, dimensions, etc., of a coverage area **185** may depend on multiple parameters such as a distance of the satellite **170** from the Earth, a width of an electromagnetic beam of the satellite, etc. For example, a wide beam from satellite **170** may result in coverage area **185** being a large area, e.g., a country, whereas a narrow beam from satellite **170** may result in coverage area **185** being smaller—e.g., such as a metropolitan area.

In the present context, terminal **105**A is a computer-based communication device that provides an interface between the IoT devices **130** (or the like) and the remote computers **135** via the satellite link(s) **145** and/or the terrestrial link(s) **140**. In one non-limiting example, the terminal **105**A may be a very small aperture terminal (VSAT). Terminal **105**A is implemented via circuits, chips, antennas, or other electronic components that can communicate with satellites **170** and terrestrial base stations **165** which are within communication range of the terminal **105**A. In some instances, the terminals **105**A are stationary relative to a location on Earth. In other instances, the terminal **105**A is mobile, meaning that the terminal **105**A moved relative to a location on the Earth. For instance, the terminal **105**A may be configured to receive communications from satellite **170** or terrestrial base station **165** and transmit such communications via the local communication network **150**, e.g., Wi-Fi, Zigbee, etc., to the IoT devices **130**. Additionally, or alternatively, the terminal **105**A may receive communication, e.g., sensor data, from IoT device(s) **130** and transmit such communication to the remote computer **135**.

With continued reference to FIG. **1**, the terminal **105**A may include a computer **110** including a processor **112** and a memory **114**, a satellite communication interface **115**, terrestrial communication interface **120**, and a local communication interface **125**. The processor may be implemented via circuits, chips, or other electronic component and may include one or more microcontrollers, one or more field programmable gate arrays (FPGAs), one or more application specific integrated circuits (ASICs), one or more digital signal processors (DSPs), one or more customer specific integrated circuits, etc. The processors in computers **110** (or other devices **130**, gateways **180**, etc.) may be programmed to execute instructions stored in the memory **114**, as discussed herein. The memory **114** includes one or more forms of computer-readable media, and stores instructions executable by the processor **112** for performing various operations, including as disclosed herein.

The satellite communication interface **115** includes physical layer components such as transceiver, modulator, demodulator, etc. to facilitate communication with satellites **170**. Terminal **105**A may include or be communicatively connected to one or more dish(s) **175** and antenna(s), which allow terminal **105**A to communicate with one or more satellites **170** at a time.

The antenna may include a low-noise block downconverter (LNB) mounted on a dish **175**, which may collect radio waves from the dish **175** and convert the collected radio waves to a signal which is sent through wired connection, e.g., a cable, to the terminal **105**A. The antenna may be a combination of low-noise amplifier, frequency mixer, local oscillator and intermediate frequency (IF) amplifier. The antenna serves as a radio frequency (RF) front end of a terminal **105**A, receiving a microwave signal from a satellite **170** collected by the dish **175**, amplifying the received signal, and converting the block of frequencies to a lower block of intermediate frequencies (IF). This conversion of RF to a lower block of IF, allows the signal to be carried, e.g., via a wired connection, to terminal **105**A. An antenna typically includes a sender antenna configured to send radio waves to a satellite **170**, and/or a receiver antenna configured to receive radio waves from satellite **170**.

The terrestrial communication interface **120** facilitates communication of the terminal **105**A with base station **165**. The terrestrial communication interface **120** is implemented via circuits, chips, or other electronic component such as a modulator, a demodulator, antenna, etc., configured to communicate via a specified frequency and communication protocol such as LTE, 5G, etc.

The local communication interface **125** facilitates communication of the terminal **105**A via the local communication network **150**, e.g., Wi-Fi. The local communication interface **125** may be implemented via chips, modulators, demodulators, antenna, etc.

As discussed above, the terminal **105**A includes satellite and terrestrial communication interfaces **115**, **120** and can communicate traffic data T via the satellite and/or terrestrial communication interface **115**, **120** (e.g., split the traffic data T between the satellite and/or terrestrial communication interfaces **115**, **120**). In this context, the computer **110** may coordinate the communication of the traffic data T via the satellite and/or terrestrial communication interfaces **115**, **120**. In the present context, a second computer **156**, e.g., included in the mobile backbone **155**, may be programmed to coordinate the communication of the traffic data T with the block **270** of terminal **105**A. Thus, when traffic data T sent from the terminal **105**A is split between the terrestrial and satellite communication interface **115**, **120**, the computer **110** of the terminal **105**A sends information to the second computer in the backbone **155** describing how the split information can be merged together, e.g., providing a list of instructions for how the data can be merged together. Thus, the second computer in the backbone can, upon receiving the portions of the traffic data T via the satellite and terrestrial communication links **140**, **145**, merge the received data together based on instructions received from the computer **110**.

FIG. **2** shows an exemplary software architecture of terminal **105**A. The exemplary blocks PHY **210** (or physical layer), RLC/MAC **220** (or Radio Link Control/Medium Access Control), and PDCP/RRC **230** (or Packet Data Convergence Protocol/Radio Resource Control), which are shown as redundant blocks, represent OSI (Open System Interconnection) layers for each of the satellite and terrestrial communication. PHY **210** represent the software programming to operate the satellite and terrestrial communication interfaces **115**, **120**. Blocks IP **240**, IoT Transport **250**, and IoT Application **260** represent programming of the terminals **105**A with respect to communication with IoT devices **130** via the local communication interface **125**.

The computer **110** implements example blocks of FIG. **2** by executing programming stored on the memory of the computer **110** and actuating components of the terminal **105**A, such as the communication interfaces **115**, **120**, **125**. Thus, computer **110** can be programmed to communicate traffic data T between the IoT devices **130** and the remote computer(s) **135**. In the present context, "traffic data T" includes any data including sensor data, actuation command, software update, etc., exchanged between devices **130** and the remote computer(s) **135**, e.g., sensor data sent from IoT devices **130** to the remote computer **135**, actuation command or software update sent from the remote computer **135** to IoT devices **130**. In the present context, t (T) returns a throughput of the traffic data T, e.g., 50 Megabit/second (Mb/s). In the present context, the operator t( ) returns a throughput of data being communicated through terminal **105**A, via satellite link **145**, and/or via terrestrial link **140**.

Session Management and Mobility Management (SM/MM block **270**) serves the underlying layers of the stack, i.e., taking advantage of the fact that protocols themselves are oblivious to whether the terminal **105**A is communicating over a satellite link **145** or terrestrial link **140**. In other words, the enhancements related to satellite link **145** and terrestrial link **140** are in the lower layers such as the physical layer PHY **210** and RLC/MAC **220**, and/or PDCP/RRC **230**. Traffic data T may be transmitted via the satellite link **145** based on a non-IP protocol. FIG. **3** illustrates an example diagram for facilitating communication between a non-IP-based satellite link **145** and an IP-based network **160**. In an example non-IP based communication, the terminal **105**A computer **110** may be programmed to send traffic data T with an identifier (e.g., 23-bit data with an extension bit) of the terminal **105**A and an IoT service provider identifier (e.g., 7 bits data with an extension bit). Thus, the data may lack any TCP (Transmission Control Protocol)/IP header. In the present context, a service provider identifier is used to identify the remote computer, e.g., an IP address of the IoT server (i.e., the remote computer **135**).

Gateway computer **180** (also shown in FIG. **1**) may include a computer programmed to receive the traffic data T including the terminal **105**A identifier and the service provider identifier, to convert the received traffic data T to IP-based data, and to communicate the generated IP-based data via IP network **160** and/or mobile backbone **155** to the remote computer **135**. The gateway **180** computer may communicate with the satellite **170** via dish **175** and satellite link **145**, as shown in FIG. **1**.

In one example, the gateway **180** computer may store, e.g., in a computer memory, a table that includes a mapping of each of the service provider identifiers and corresponding IP addresses. The gateway **180** computer may be programmed to send a TCP/IP or UDP/IP data packet to remote computer **135** by determining the IP address of the remote computer **135** based on the stored table and the receive service provider identifier. The generated IP-based message may further include the terminal **105**A identifier. The remote computer **135** may be programmed to transmit data for the terminal **105**A including the received terminal **105**A identifier and an IP address of the gateway **180**. Similarly, the gateway **180** computer may be programmed to generate data for sending via the satellite link **145** to the respective terminal **105**A based on the received terminal **105**A identifier.

Computer **110** of terminal **105**A can be programmed to determine that the traffic data T, communicated via the terrestrial communication interface **140**, exceeds a threshold, and based on the determination, route at least a portion of traffic data T via the satellite communication interface **145** in accordance with a predetermined traffic data load-balancing scheme. In the present context, as discussed below, a threshold is (i) a number with a unit, e.g., a data throughput threshold D_T of 50 Megabit/second (Mb/s), or (ii) a number without a unit, e.g., a score threshold S_T, a ratio, etc.

In one example, a load-balancing scheme includes a set of rules with an objective of balancing traffic load (e.g., data transmission rate) between the terrestrial and satellite communication links **140**, **145**. In the present context, a traffic load includes (i) data transmitted by the terminal **105**A to the remote computer(s) **135**, e.g., data received from one or more IoT devices **130** via the local communication network **150**, and/or (ii) received from the remote computer(s) **135**, e.g., to be transmitted to the IoT devices **130** via the location communication network **150**. Herein, various non-limiting examples of load-balancing schemes are disclosed, according to which a terminal **105**A computer **110** can be programmed to operate. Table 1 shows an example set of rules that can be used to balance the traffic load in the system **100**. For example, the terminal **105**A computer **110** may be programmed to operate based on one or more of the rules of Table 1.

TABLE 1

No.	Condition	Description
1	Terrestrial data throughput (or data rate) exceeding a fixed data throughput threshold D_T.	A portion T_S of traffic data T is communicated via a satellite link when data throughput of the terrestrial link $t(T_T)$ exceeds a fixed (e.g., stored in memory) threshold D_T, e.g., 50 (Mb/s). The portion for communicating via the satellite link is determined such that a rest of the throughput of the terrestrial link is less than the specified threshold D_T.
2	A score of data traffic exceeds a score threshold S_T.	A score of data traffic determined based on a data rate, a data volume, and a data priority exceeds a score threshold S_T, e.g., 1. A portion of data for communication via the satellite link may be determined based on the determined score, e.g., Table 2.
3	A first score of terrestrial link exceeds a second score of satellite link.	The traffic data T is split between the satellite and terrestrial links such that a specified balance between the first and second score is maintained, e.g., first score less than second score, first score at least 30% less than second score, first score less than half of second score, etc.

FIG. **4** shows a flowchart of a non-limiting example process **400** for balancing traffic data T between terrestrial and satellite communication networks based on rules 1 and/or 2 of Table 1. The computer **110** may be programmed to execute blocks of the exemplary process **400**.

The process **400** begins in a block **410**, in which the computer **110** determines a data throughput t (T) or a score S of traffic data for the terminal **105**A. In one example, the computer **110** may be programmed to determine a data throughput t(T), e.g., in Mb/s, Gb/s, etc., of the terminal **105**A, e.g., based on data analysis techniques, etc. The data throughput t(T) may include a unidirectional, e.g., sent out to the remote computer **135** by the terminal **105**A. In another example, the computer **110** may be programmed, based on an equation (1), to determine a score S of the terminal **105**A traffic load based on a data throughput t(T), and a data type quantifier Q_D. The function f_1 returns a score for the terminal **105**A traffic load. The score S may be a number within a specified range, e.g., 1 to 10. In one example, the function f_1 may be a linear function, e.g., $S=aT+b\ Q_D$, wherein parameters a and b are based on empirical methods. The computer **110** may be programmed to determine the data type quantifier Q_D based on equation (2).

$$S=f_1(T, Q_D) \tag{1}$$

$$Q_D=f_2(V, P) \tag{2}$$

In the present context, a data quantifier Q_D is a measure to quantify data parameters which are relevant for a determination whether to communicate the data via terrestrial link **140** or satellite link **145**. In one example, the computer **110** may be programmed, based on equation (2), to determine the data quantifier Q_D based on data volume V and data priority P. The computer **110** may be programmed to determine the data volume V based on data received from a sender of the data, and/or other data analysis techniques. For example, the terminal **105**A may determine a volume V of a bulk upload based on a data header transmitted at a beginning of a software update. The data volume V is volume, e.g., specified in Mb, Gb, etc., of data being transferred via the terminal **105**A. For example, a volume V of a bulk upload is a volume of software downloaded from the remote computer **135** to a plurality of IoT devices **130**.

In the present context, data priority P is a measure for specifying a criticality of transferring the traffic data T without interruption and/or delay. Table 2 shows example levels of, data priority P. The computer **110** may be programmed to determine data priority P based at least in part on a latency threshold L_T of the traffic data T. For example, the computer **110** may be programmed to determine a high priority level upon determining that a maximum latency threshold L_T of the traffic data T is less than or equal 100 millisecond (ms). The computer **110** may be programmed to detect a type of traffic data T, e.g., using deep packet inspection, packet header classification, or other traffic classification techniques, and to determine the latency threshold L_T based on the detected type of data.

TABLE 2

Type	Description	Priority P	Latency L_T (ms)
High priority	Time sensitive data.	−1	<10 ms
Normal	Less time sensitive but error sensitive data.	0 (zero)	<150 ms
Low priority	Not time sensitive data.	1	>1 150 ms

Next, in a decision block **420**, the computer **110** determines whether a data throughput threshold D_T and/or a score threshold S_T is exceeded. In one example, the computer **110** may be programmed to determine whether the data throughput t(T) exceeds the data throughput threshold D_T, e.g., 50 Mb/s. In another example, the computer **110** may be programmed to determine whether the terminal **105**A score S exceeds a score threshold S_T, e.g., 5. The computer **110** may be programmed to store the score threshold S_T in a computer **110** memory and/or to receive the score threshold S_T from a second computer such as the remote computer **135**. If the computer **110** determines that the data throughput t(T) exceeds the data throughput threshold D_T and/or the score S exceeds the score threshold S_T, then the process **400** proceeds to a block **430**; otherwise the process **400** proceeds to a block **440**.

In the block **430**, the computer **110** identifies at least a portion T_S, of the traffic data to be routed via the satellite link **145** between the terminal **105**A and a satellite **170**. The computer **110** routes a portion of the traffic data via the satellite link **145** to balance the traffic data T between the satellite link **145** and the terrestrial link **140**. In one example, the computer **110** may be programmed to determine the data portion T_S to be routed via the satellite link **145** based on the data throughput t(T), the threshold D_T, and a capacity C of the satellite link **145**. In the present context, a data portion T_S includes a set of data, e.g., list of data packet identifiers, etc., that identifies specific parts of data from the traffic data. In the present context, $t(T_S)$ returns a throughput of the data portion T_S. The computer **110** may determine the throughput of the data portion $t(T_S)$ based on the identified data packets included in the data throughput portion T_S. For example, upon determining that the data portion T_S includes a data packet from IoT sensor **130** with a rate to be sent every second with a volume V of 1 megabit, the computer **110** determines that data portion throughput $t(T_S)$ is 1 Mb/second (Mb/S). For example, the computer **110** may be programmed, based on equation (3) to determine the data portion T_S. In the present context, a capacity C of a satellite link **145** is a maximum data throughput, e.g., 10 Gb/s, that the respective satellite link **145** provides.

$$t(D_S) = \begin{cases} t(T) - D_T & \text{if } T - D_T < C \\ C & \text{if } T - D_T \geq C \end{cases} \quad (3)$$

In another example, the computer **110** may be programmed to determine the data portion T_S for satellite link **145** based on the score threshold S_T. For example, the computer **110** may be programmed to determine the data portion D_S such that $S_M = f_1(T - T_S, Q_D) < S_T$. In other words, the computer **110** may determine a portion of the traffic data such that a score of the data T_T (i.e., the data $T - D_S$) routed via the terrestrial link **140** is less than the score threshold S_T. For example, as shown in Table 3, the computer **110** may be programmed to identify low priority portions of the traffic load, e.g., bulk upload data, for being routed via the satellite link **145**, such that the score S_M of the data routed via the terrestrial link **140**, e.g., a mobile network, is below the score threshold S_T. Thus, with reference to Table 3, $T - T_S$ (or T_T) represents a subtraction of a set of data T_S from another set of data, in contrast to an algebraic subtraction.

TABLE 3

Data components	T	T_S	T_T
High priority data transmitted from IoT device uploaded to remote computer	√		√
High priority data for a second IoT device transmitted from remote computer	√		√
Low priority bulk upload transmitted from IoT device to a remote computer	√	√	

In the block **440**, the computer **110** may be programmed to route the data portion T_S via the satellite link **145** and the rest of data T_T via the terrestrial link **140**. The computer **110** may actuate the satellite communication interface **115** and/or the terrestrial communication interface **120**, as discussed with reference to FIGS. **1-2**, to route the data via the satellite and/or terrestrial links **140**, **145**. Routing of data by the terminal **105**A computer **110** is further discussed with respect to FIGS. **9**A-**9**B.

Following the block **440**, the process **400** ends, or alternatively returns to the block **410**, although not shown in FIG. **4**.

FIG. **5** shows a flowchart of another non-limiting example process **500** for balancing the data traffic on example rule 3 of Table 1. The computer **110** may be programmed to execute blocks of the exemplary process **500**.

The process **500** begins in a block **510**, in which the computer **110** determines a data type quantifier Q_D, as discussed above.

Next, in a block **520**, the computer **110** determines a terrestrial link quantifier Q_M and a satellite link quantifier Q_S for the terrestrial link(s) **140** and the satellite link **145** respectively. The link's quantifiers Q_M, Q_S may be numbers within a specified range, e.g., 1 to 6. With reference to Table 4, the computer **110** may be programmed to determine the link quantifiers Q_M, Q_S based on a data rate capacity of the links **140**, **145**, link condition, e.g., weather conditions, etc. In the present context, a link condition may be specified in percentage, e.g., 100% is a perfect condition such as no rain, no wind, no physical obstacle, etc., whereas 50% reflects a compromised link **140**, **145** condition such as inclement weather, etc. Table 4 shows a non-limiting example of quantifiers Q_M, Q_S, capacity of link **140**, **145**, and a link condition. In one example, the computer **110** may be programmed to determine the quantifiers Q_M, Q_S based on data stored in computer **110** memory such as Table 4.

TABLE 4

Quantifier Q_M, Q_S	Capacity of link	Link Condition
1	C > 1 Gb/s	100%
2	50 Mb/sec < C < 1 Gb/s	100%
3	C < 50 Mb/sec	100%
4	C > 1 Gb/s	50%
5	50 Mb/sec < C < 1 Gb/s	50%
6	C < 50 Mb/sec	50%

Next, in a block **530**, the computer **110** determines a terrestrial communication score S_M and a satellite traffic data score S_S. The computer **110** may be programmed to determine the terrestrial traffic data score S_M based on data portion T_T routed through the terrestrial link **140** (e.g., $T = T_T$, if the traffic data is routed entirely through the terrestrial link(s) **140** of the terminal **105**A), the volume V of data, and the terrestrial link quantifier Q_M, e.g., based on equation (3). The computer **110** may be programmed to determine the satellite traffic data score S_S based on data throughput Ts, the volume V of data, and the satellite link quantifier Qs, e.g., based on equation (4). Equation (5) shows the relationship of traffic data T with portions T_T and T_S routed through each of the terrestrial and satellite links **140**, **145**.

$$S_M = f_2(T_T, V, Q_M) \quad (3)$$

$$S_S = f_3(T_S, V, Q_S) \quad (4)$$

$$T = T_T + T_S \quad (5)$$

Typically, routing a large number of smaller data packets (i.e., lower volume V) via terrestrial link **145** has less overhead, e.g., establishing connection, etc., compared to routing same large number of smaller packets via satellite link **145**. Similarly, routing large volume V of data via satellite link **145** has less overhead compared to routing same data via terrestrial link **140**, e.g., mobile communication. In one example, the functions f_2, f_3 may be specified such that transferring data T with small volumes V returns a lower score S_M whereas returning a higher score S_S. For example, volume V may be a numerator in function f_2 whereas it is a denominator in the function f_3.

Next, in a decision block **540**, the computer **110** determines whether the terrestrial score S_M exceeds the satellite score S_S. If the computer **110** determines that the terrestrial score SM exceeds the satellite score S_S, then the process **500** proceeds to a block **550**; otherwise the process **500** proceeds to a block **560**.

In the block **550**, the computer **110** identifies data portion T_S and/or updates the data portion T_S (as discussed with reference to the block **530**). For example, the computer **110** may be programmed to identify the data portion T_S such that the terrestrial score S_M is less than or equal the satellite score S_S. For example, the computer **110** may be programmed to modify the set of data T_S to increase a volume V of data T_S, e.g., by placing high volume V bulk upload in data portion T_S, as shown in Table 3).

In the block **560**, the computer **110** routes the traffic load based on the identified data portion T_S for the satellite link **145**. The computer **110** may be programmed to route the data portion T_S via the satellite link **145** and to route the rest of data T_T via the terrestrial link **140**. Further details of routing data are discussed below with reference to FIGS. **9**A-**9**B.

FIG. **6** shows a system **600** including a plurality of terminals **105**A, **105**B, **105**C and a plurality of IoT devices **130** communicating via the plurality of terminals **105**A, **105**B, **105**C with the remote computer(s) **135**. In at least one example, terminals **105**B and **105**C (and their programming/operation) are similar or identical to terminal **105**A; accordingly, these will not be re-described herein. While three terminals are shown in this figure, any suitable quantity of terminals may be used. The base station **165** and/or the multicast gateway (MCG **610**) may communicate with the remote computer **135** via the mobile backbone **155**, IP network **160**, etc., although not shown in FIG. **6**.

As discussed above, the traffic load may include data transmitted by the remote computer(s) **135** to the IoT devices **130**, e.g., a software update. In one example, synchronous software upgrade of the plurality of IoT devices **130** in the system **600** can be achieved using satellite **170** communication forward channel multicast (or broadcast) operation. In a forward channel multicast operation (or multicast mode), one set of data is sent to terminals **105**A, **105**B, **105**C (i.e., a one-to-many communication) within coverage area **185** of satellite **170**, in contrast to a unicast communication (or communication in unicast mode) in which a one-to-one communication to each receiver is established. For example, a SDL (Software Downline Load) protocol can be used for a multicast software update. For example, the software update data packets can be uploaded via an uplink **145**D to the satellite **170** and then transmitted concurrently in a multicast operation via downlinks **145**A, **145**B, **145**C to the terminals **105**A, **105**B, **105**C, e.g., via a beam that covers a geographical area in which the respective terminals are located. Typically, in a mobile backbone **155**, IP network **160**, data is transferred through unicast. As shown in FIG. **6**, a Multicast Gateway (MCG **610**) may operate as a router for the terminals **105**A, **105**B, **105**C which participate in a multicast session. The satellite **170** gateway **180** may then receive multiple unicast streams from MCG **610** and select one of the received streams and transmit the selected stream via the satellite **170** beam, as further discussed with respect to FIG. **7**. MCG **610** typically keeps track of the terminals **105**A, **105**B, **105**C that have joined a multicast session and determines a modulation and a coding scheme, as well as power level to reach all the terminals **105**A, **150**B, **105**C.

In one example, remote computer **135** of a utility company managing a smart grid may deliver a command to a group of actuators IoT devices **130** by multicasting via MCG **160** and terminals **105**A, **105**B, **105**C. Thus, by multicasting instead of delivering individual commands to each IoT device **130** via separate mobile terrestrial communication links **140**, signaling congestion and communication loads may be reduced. For multicasting purposes, devices **130** can be grouped based on which need the same downlink control messages (e.g., commands for actuators) and/or data packets (e.g., firmware/configuration or information file download). Additionally, or alternatively, the devices **130** can be grouped based on their service requirements (i.e. multicasting scenarios) or their physical location (i.e., geocasting scenarios), to reduce a signaling congestion on the air and/or to reduce the traffic load.

To protect satellite data communication against cyber-attacks, traffic data during a multicast may be encrypted. In an encrypted unicast communication, a sender of data may encrypt the data with an encryption key of a receiver and send the encrypted data to the receiver. In one example, an encryption technique such as PKI (Public Key Infrastructure), etc. may be used. The receiver may decrypt the received encrypted data based on the receiver's key, using known encryption techniques. However, an intruder computer may lack the encryption key of the receiver. Therefore, a cyber-attack may be prevented because the intruder computer, which eavesdrops decrypted data, cannot decrypt the encrypted data without possessing the encryption key.

Given an objective of achieving resource efficiencies by transmitting only one copy of data, e.g., via a spot beam, to reach multiple terminals **105**A, **105**B, **105**C, which have joined a same multicast session, a unicast encryption technique may not be satisfactory, because each of the receivers of data (i.e., terminals **105**A, **105**B, **105**C) may have a different encryption key. FIG. **7** is a sequence diagram **700** which illustrates a non-limiting example use case for multicasting encrypted data to a plurality of terminals **105**A, **105**B, **105**C. The remote computer **135**, MCG **610**, satellite gateway **180**, and terminals **105**A, **105**B may be programmed to execute actions of the sequence diagram **700**. Although, the diagram **700** shows two terminals **105**A, **105**B, the disclosed method can be applied to any number of terminals **105**A, **105**B.

The sequence diagram **700** starts by terminals **105**A, **105**B performing a unicast security association with the gateway **180** (steps **710**, **720**). For example, the gateway **180** may communicate with each of the terminals **105**A, **105**B and receive the encryption key **K1**, **K2** data of each of the terminals **105**A, **105**B. Thus, upon performing the unicast operations, the gateway **180** possesses encryption keys **K1**, **K2**.

Upon receiving an Internet Group Management Protocol (IGMP) join message (step **730**, **765**) from terminal **105**A, the gateway computer **180** may transmit via the MCG **610** a PIM (Protocol Intendent Message) join message to the remote computer **135** (steps **740**, **750**, **770**). The IGMP is a communications protocol used to establish multicast group memberships. PIM is a family of multicast routing protocols for IP networks **160** that provide one-to-many and many-to-many distribution of data over an IP-based network.

The gateway computer **180** may generate a common key Km for a multicast session. As will be explained below, the generated common key Km will be same for all terminals **105**A, **105**B (of the session), thus preventing a need for unicast transmission of encrypted data to each respective terminal. The gateway computer **180** may distribute the multicast security key Km via a unicast communication to each of the terminals **105**A, **105**B using individual keys **K1**, **K2** (step **760**). Thus, after receiving the distributed common key Km, each of the terminals **105**A, **105**B will be able to decrypt data encrypted with the common key Km.

The remote computer **135** may send multicast data packet P**1** to the MCG **610** (step **780**). MCG **610** may transmit the message via an IP-based network through multiple unicast messages to the gateway **180** (steps **785**, **790**), whereas as shown in the diagram **700**, the gateway **180** will then select one of the streams, encrypt the data with the common key Km, and multicast the encrypted packet P**1** to the terminals **105**A, **105**B (step **795**).

Upon receiving the encrypted multicast data, each of the terminals **105**A, **105**B may be programmed to decrypt the received multicast data based on the stored common key

Km. Thus, the satellite **170** may multicast the data packet P**1** to the plurality of terminals **105**A, **105**B, and each of those terminals **105**A, **105**B may concurrently receive the data, multicasted by the satellite **170**.

As discussed above, a condition of satellite link **145** may vary, e.g., based on weather condition, obstacles, etc. With reference to FIG. **6**, when satellite **170** multicasts data to the plurality of terminals **105**A, **105**B, **105**C, a reception of different terminals **105**A, **105**B, **105**C may differ. For example, terminal **105**A may support a high spectral efficiency (i.e., high data rate for a given bandwidth) compared to terminal **105**B. The satellite **170** computer **172** and/or the gateway **180** may be programmed to determine multicast parameters, e.g., data rate, frequency of the beam, etc., in accordance with a poorest link condition, i.e., such that the terminal with a lowest reception among the terminals **105**A, **105**B, **105**C is expected to support the received multicast data.

Although this approach may be helpful in providing a possibility of multicasting data to the plurality of terminals **105**A, **105**B, **105**C with a wide range of link conditions, power level, etc., but it may not be efficient because it may not utilize the terminals with a higher link condition, etc. In other words, by configuring the multicast based on low performing terminals (i.e., with lower link conditions), the satellite **170** may not utilize the terminals which support, e.g., higher data rate, frequency, etc.

In one example, discussed here below with reference to FIG. **8**, the terminals **105**A, **105**B, **105**C may be divided into subgroups based on the respective link conditions, physical attributes, etc. In the present context, physical attributes of terminals **105**A, **105**B, **105**C are specific parameters of the satellite communication interface **115**, antenna, etc., such as modulation, coding, power, etc. In the present context, a subgroup includes the plurality of terminals **105**A, **105**B, **105**C being located within the coverage area **185** of the satellite **170** and being selected based on the respective physical attributes and/or link conditions.

FIG. **8** shows a sequence diagram **800** including a link adaptation portion **810**. With reference to the portion **810** of the diagram **800**, the satellite **170** computer **172** may be programmed to receive, via a satellite uplink **145**, a quality status R_Q including a link condition, and to adjust, based on the received quality status R_Q, at least one of multicast parameters including a data throughput, a transmission power, and a transmission spectral efficiency. Spectral efficiency is an information rate that can be transmitted over a given bandwidth in a specific communication system, e.g., measured in bit/s/Hz.

With reference to FIGS. **7** and **8**, the sequence diagram **800** illustrates a similar sequence such as shown in FIG. **7** up to broadcasting the common encryption key Km to the terminals **105**A, **105**B (step **775**). However, after that step **775**, based on the sequence diagram **800**, the satellite **170** computer may adjust the multicast parameters based on quality status R_Q received from the terminals **105**A, **105**B (steps **820**, **830**, **840**, **850**), as further discussed with reference to FIGS. **9**A-**9**B.

FIGS. **9**A-**9**C are a flowchart of a process **900** for operating satellite **170**. For example, a gateway computer **180** may be programmed to execute blocks of the process **900**.

The process **900** begins in a block **910** in which the gateway computer **180** determines whether traffic data T_S is received from terminal(s) **105**A, **105**B, **105**C, e.g., sensor data which terminals **105**A, **105**B, **105**C received from IoT devices **130**. If the gateway computer **180** determines that traffic data is received from one or more terminals **105**A, **105***b*, **105**C, then the process **900** proceeds to a block **915**; otherwise the process **900** proceeds to a decision block **920**.

In the block **915**, the gateway computer **180** routes the traffic data T_S via satellite **170** downlink **145** to remote computer **135**, e.g., an IoT server. The gateway computer **180** may route the traffic data T_S via the gateway **180**, the mobile backbone **155**, and/or the IP network **160** to the remote computer **135**, e.g., an IoT server.

As discussed with reference to FIG. **1**, the traffic data T received from the terminals **105**A, **105**B, **105**C may be split by the terminal **105**A, **105**B, **105**C to data T_T for terrestrial link **140** and data T_S for the satellite link **145**. A computer of the mobile backbone **155** may merge the traffic data T_T received via the terrestrial link **140** and data T_S received from the satellite **170** downlink **145** in accordance with the determination of the respective terminal **105**A, **105**B, **105**C to split the data (as discussed above with reference to the block **270** of FIG. **2**). Further, the computer of the mobile backbone **155** may split the traffic data going out from the remote computer **135** to the terminals **105**A, **105**B, **105**C based on determination made at the terminal **105**A, **105**B, **105**C, and/or determination made at the backbone **155** and/or gateway **180** on how to split the data transmitted to the terminals **105**A, **105**B, **105**C between the links **140**, **145**. In one example, such determination may be made based on similar techniques discussed with respect to equations (1)-(5).

In the decision block **920**, the gateway computer **180** determines whether data is received from the remote computer **135** for multicast to terminals **105**A, **105**B, **105**C. In other words, gateway computer **180** may determine whether a multicast session is needed. Additionally, or alternatively, the gateway computer **180** may determine that a multicast session is needed based on IGMP join messages received from the terminals **105**A, **105**B, **105**C (see FIGS. **7**-**8**). The gateway computer **180** may be programmed to communicate based on a PIM protocol with the remote computer **135**. If the gateway computer **180** determines that data for multicast is received and/or IGMP join messages are received, then the process **900** proceeds to a block **925**; otherwise the process **900** proceeds to a decision block **955** (see FIG. **9**C).

In the block **925**, the gateway computer **180** performs a unicast security association. The gateway computer **180** may be programmed to receive terminals **105**A, **105**B, **105**C encryption keys K**1**, K**2**, K**3** and store in gateway computer **180** memory. Additionally, or alternatively, the gateway computer **180** may be programmed to send a request for the encryption keys K**1**, K**2**, K**3** to the terminals **105**A, **105**B, **105**C, and to store the received keys K**1**, K**2**, K**3**.

Next, in a block **930**, the gateway computer **180** distributes the common key Km to the terminals **105**A, **105**B, **105**C. The gateway computer **180** may be programmed to send the common key Km to each of the terminals **105**A, **105**B, **105**C using the individual keys K**1**, K**2**, K**3** of each terminal **105**A, **105**B, **105**C.

Next, in a block **935**, gateway computer **180** transmits a request for a quality status R_Q to each of the terminals **105**A, **105**B, **105**C. For example, gateway computer **180** may be programmed to multicast a specified data to the terminals **105**A, **105**B, **105**C with a set of different specified data rates, power levels, and frequencies. The specified data and/or the set of data rates, etc. may be stored in a gateway computer **180** memory.

Next, as shown in FIG. **9**B, the gateway computer **180** determines whether quality statuses R_Q are received from the terminals **105**A, **105**B, **105**C. In the present context, a quality status R_Q of a terminal **105**A, **105**B, **105**C includes information describing how successful satellite link **145** routes data between the satellite **170** and the respective terminal **105**A, **105**B, **105**C. In one example, a quality status R_Q describes the link condition. In one example, a quality status R_Q includes a link condition specified in a percentage value. Additionally, or alternatively, the quality status R_Q includes data such as a percentage of corrupted data received, etc. The gateway computer **180** may store the quality status R_Q of each of the terminals **105**A, **105**B, **105**C in the gateway computer **180** memory, e.g., in a table. If the quality statuses quality status R_Q are received, the process **900** proceeds to a block **945**; otherwise the process **900** returns to the decision block **940**. Alternatively, the process **900** may end or proceed without the quality status quality status R_Q, although not shown in FIG. **9**B.

In the block **945**, the gateway computer **180** determines groups of terminals **105**A, **105**B, **105**C for multicast and further determines multicast parameters, e.g., data rate, spectral efficiency of the beam, etc., based on the received quality status R_Q. For example, the gateway computer **180** may divide, based on the received quality status R_Q, the terminals **105**A, **105**B, **105**C into a first group of terminals **105**A, **105**C with a first set of multicast parameters and a second group of terminal(s) **105**B with a second set of multicast parameters. For example, as shown in Table 5, the gateway computer **180** may determine a first group having terminals **105**A, **105**C with quality status R_Q values 95% and 80%, and a second group having the terminal **105**B with quality status R_Q value 50%, based on the quality statuses R_Q. In one example, the multicast of data with the first set and second set of multicast parameters may be via a same beam of the satellite **170**. In another example, multicasting of the data with the first and second set of parameters may be via a first and a second beam of the satellite **170** that overlap.

As shown in Table 5, the gateway computer **180** may determine corresponding multicast parameters for each group, e.g., "High," and "Low". In an example, the gateway computer **180** may determine multicast parameters based on a table such as Table 6. Table 6 shows an example for defining multicast parameters as a "High", "Medium", or "Low" level. Each of the levels may be associated with a specific data rate, spectral efficiency, etc. For example, power may be maintained constant but by changing modulation and/or coding data rate may be adjusted. The spectral efficiency is an indicator of modulation and coding scheme. As shown in Table 6, the gateway computer **180** may determine the terminals **105**A, **105**C with a quality status R_Q exceeding a quality threshold 75% as a first group with multicast parameter "High" level, whereas determines the terminal **105**B with the quality status R_Q of 50% (which is less than the threshold 60% of Table 6) as the second group with multicast parameter "low" level. Additionally, or alternatively, the computer may be programmed to group the terminals **105**A, **105**B, **105**C based on other techniques, e.g., using statistical methods to identify groups with a deviation of quality status R_Q less than a deviation threshold. Additionally, or alternatively, the gateway computer **180** may be programmed to determine the multicast parameters using other techniques, e.g., adjusting each of the data rate, power, etc., for a group based on an average quality statuses R_Q received from the terminals **105**A, **105**B, **105**C of the respective group.

TABLE 5

Groups	Terminals	Quality Status	Multicast Parameters
1	105A, 105C	95%, 80%	High
2	105B	50%	Low

TABLE 6

Multicast parameter set	Data rate (Mbps)	Spectral Efficiency (bits/s/Hz)	Quality Status threshold
High	81.2 Mbps	1.624	75%
Medium	60.8 Mbps	1.216	60%
Low	36.3 Mbps	0.725	0%

Next, in a block **950**, the gateway computer **180** multicast the data to the terminals **105**A, **105**B, **105**C based on the first set of multicast parameters via a first downlink **145**, and multicast the data based on the second set of multicast parameters via a second downlink **145**. For example, with respect to Table 5, the gateway computer **180** may be programmed to multicast data with "high" level multicast parameters to the terminals **105**A, **105**B, and with the "low" multicast parameters to the terminal **105**B. In one example, the first and second downlinks **145** may be included in a same beam of the satellite **170**. In another example, the first and second links **145** may be in different beam of the satellite **170**. Following the block **950**, the process **900** proceeds to a decision block **955** (see FIG. **9**C).

With reference to FIG. **9**C, following either of the blocks **920** of FIG. **9**A or the block **950** of FIG. **9**B, in the decision block **955**, the gateway computer **180** determines whether data is received from the remote computer **135** for terminal **105**A, **105**B, **105**C. If the gateway computer **180** determines that data for transmitting to a terminal is received from the remote computer **135**, e.g., via the IP network **160**, backbone network **155**, etc., then the process **900** proceeds to a block **960**; otherwise, the process **900** ends, or alternatively returns to the block **910**, although not shown in FIG. **9**C.

In the block **960**, the gateway computer **180** sends the received data to the respective terminal(s) **105**A, **105**B, **105**C. The gateway computer **180** may determine the receiver terminal **105**A, **105**B, **105**C of the data based on, e.g., header data including a terminal identifier, as discussed above with reference to FIG. **3**. Following the block **960**, the process **900** ends, or alternatively returns to the block **910**, although not shown in FIG. **9**C. As another example, a satellite **170** computer **172** may be programmed to execute one or more blocks of the process **900**.

FIGS. **10**A-**10**B show a flowchart of a process **1000** for routing data via the terrestrial and satellite interfaces **115**, **120**. The process **1000** specifies what may be performed in the blocks **440** or **560** of the processes **400**, **500** to route the traffic data T, e.g., by sending out IoT devices **130** data to the remote computer **135** and/or receiving traffic data from the remote computer **135** and sending the received data to the IoT devices **130**. For example, the terminal **105**A computer **110** may be programmed to execute blocks of the process **1000**.

The process **1000** begins in a block **1010**, in which the computer **110** performs unicast security association. The computer **110** may be programmed to exchange encrypted information with the satellite **170** computer **172** and/or the gateway **180** (see FIGS. **7**-**8**) and provide the terminal **105**A specific key K1 to the computer **172** and/or the gateway **180** computer.

Next, in a decision block **1015**, the computer **110** determines whether a common encryption key Km is received. With further reference to FIGS. **7**-**8**, the computer **110** may be programmed to receive a common key Km encrypted based on the terminal **105**A key **K1** via the satellite link **145**A. If the computer **110** receives the common key Km, then the process **1000** proceeds to a block **1020**; otherwise the process **1000** returns to the decision block **1015**.

In the block **1020**, the computer **110** stores the received common key Km in a computer **110** memory. As discussed below, the computer **110** may decrypt the data multicast by the satellite **170** based on the stored common key Km.

Next, in a decision block **1025**, the computer **110** determines whether encrypted multicast data is received. The computer **110** may be programmed to determine whether the received data is multicast data based on various techniques, e.g., based on determining that the received data is addressed (e.g., based on the terminal identifier) for a plurality of terminals **105**A, **105**B, **105**C rather than specifically being addressed for the terminal **105**A. If the computer **110** determines that encrypted multicast data is received, then the process **1000** proceeds to a block **1030**; otherwise the process **1000** proceeds to a decision block **1040** (see FIG. **10**B). Alternatively, the blocks **1010** to **1030** may be omitted, e.g., when no encrypted multicast is performed.

In the block **1030**, the computer **110** decrypts the received encrypted data based on the received common key Km.

Next, in a block **1035**, the computer **110** routes the decrypted data to the connected devices **130**. For example, the computer **110** may be programmed to route the decrypted data to a plurality of IoT devices **130** via a local communication network **150**. Non-limiting examples of locally-connected IoT devices **130** include temperature sensor, pressure sensors, utility company switching actuator, a programmable controller such as thermostat, etc. Following the block **1035**, the process **1000** proceeds to a decision block **1040** (see FIG. **10**B).

In the block **1040**, the computer **110** determines whether a request for the quality status R_Q is received. In one example, the request for quality status R_Q may be a multicast message transmitted by the satellite to all terminals **105**A, **105**B, **105**C. In another example, the request for quality status R_{Qmay} be a message individually addressed to the respective terminal **105**A, **105**B, **105**C, e.g., including the terminal identifier. If the computer **110** determines that a request for quality status R_Q is received, then the process **1000** proceeds to a block **1045**; otherwise the process **1000** proceeds to a decision block **1050**.

In the block **1045**, the computer **110** determines the quality status R_Q and sends the determined quality status R_Q to the satellite **170**. The computer **110** may be programmed to determine the quality status R_Q based on evaluating the communication via the satellite link **145**A, e.g., determining link condition, etc. In one example, the computer **110** may store a table in the computer **110** memory that describes a relationship of quality status R_Q with various parameters such as received power level, link condition, percentage of corrupted data, etc.

Next, in a decision block **1050**, the computer **110** determines whether aggregating of traffic data for satellite link **145**A is necessary. As discussed with respect to the function f_3 in equation (4), transmitting small packets of data may increase the score S_S. Upon determining that a number of small data packets (e.g., packets with a volume V less than a threshold, e.g., 1 kilobyte) exceeds a threshold, e.g., 100, the computer **110** may be programmed to determine that the identified small packets may be aggregated to reduce the score S_S of the data being transmitted via the satellite link **145**A.

In the block **1055**, the computer **110** aggregates the identified data packets in an aggregated data packet including each of the small data packets. The computer **110** may be programmed to update the data portion T_S for the satellite communication to replace the small data packets with the aggregated data packet. In one example, data aggregation may be implemented as a proxy server at satellite terminal **105**A, **105**B, **105**C. In the present context, "updating" means replacing the small individual data packets from the data portion T_S and storing instead the aggregated data packet in the data portion T_S. Thus, by updating the data portion T_S for the satellite communication, the satellite link **145** may be utilized more efficiently because by aggregating the data packets a volume V of the data portion T_S will be reduced.

Next, in a block **1060**, the computer **110** may be programmed to transmit the identified data portion T_S for satellite communication via the satellite link **145**A. The computer **110** may be programmed to actuate the satellite communication interface **115** to route the data portions T_S.

Next, in a block **1065**, the computer **110** routes the rest of the data, i.e., the data portion T_T for the terrestrial communication via the terrestrial link **140**. The computer **110** may be programmed to actuate the terrestrial communication interface **120** to transmit the data portion T_T. Following the block **1065**, the process **1000** ends, or alternatively returns to the block **1010**, although not shown in FIG. **10**B.

Thus, there has been described a communication system that comprises a satellite terminal having a terrestrial communication interface, a satellite communication interface, and a computer. The terrestrial and satellite communication interfaces can be configured to communicate traffic data. The satellite terminal system can further include a computer communicatively linked to the terrestrial and satellite communication interfaces. According to one example, a computer of the terminal system may be programmed to determine that the traffic data, communicated via the terrestrial communication interface, exceeds a threshold, and based on the determination, route at least a portion of traffic data via the satellite communication interface in accordance with a predetermined traffic data load-balancing scheme.

According to another example, a satellite gateway computer may be programmed to receive, via a satellite uplink, a reception quality status including a link condition, and to adjust, based on the received quality status, at least one of multicast parameters including a data throughput, a transmission power, and a transmission spectral efficiency.

In general, the computing systems and/or devices described may employ any of a number of computer operating systems, including, but by no means limited to, versions and/or varieties of the Microsoft Windows® operating system, the Unix operating system (e.g., the Solaris® operating system distributed by Oracle Corporation of Redwood Shores, Calif.), the AIX UNIX operating system distributed by International Business Machines of Armonk, N.Y., the Linux operating system, the Mac OSX and iOS operating systems distributed by Apple Inc. of Cupertino, Calif., the BlackBerry OS distributed by Blackberry, Ltd. of Waterloo, Canada, and the Android operating system developed by Google, Inc. and the Open Handset Alliance. Examples of computing devices include, without limitation, network devices such as a gateway or terminal, a computer workstation, a server, a desktop, notebook, laptop, or handheld computer, or some other computing system and/or device.

Computing devices generally include computer-executable instructions, where the instructions may be executable by one or more computing devices such as those listed above. Computer-executable instructions may be compiled or interpreted from computer programs created using a variety of programming languages and/or technologies, including, without limitation, and either alone or in combination, Java™, C, C++, Visual Basic®, Java Script®, Perl, etc. Some of these applications may be compiled and executed on a virtual machine, such as the Java Virtual Machine, the Dalvik virtual machine, or the like. In general, a processor (e.g., a microprocessor) receives instructions, e.g., from a memory, a computer-readable medium, etc., and executes these instructions, thereby performing one or more processes, including one or more of the processes described herein. Such instructions and other data may be stored and transmitted using a variety of computer-readable media.

A computer-readable medium (also referred to as a processor-readable medium) includes any non-transitory (e.g., tangible) medium that participates in providing data (e.g., instructions) that may be read by a computer (e.g., by a processor of a computer). Such a medium may take many forms, including, but not limited to, non-volatile media and volatile media. Non-volatile media may include, for example, optical or magnetic disks and other persistent memory. Volatile media may include, for example, dynamic random-access memory (DRAM), which typically constitutes a main memory. Such instructions may be transmitted by one or more transmission media, including coaxial cables, copper wire and fiber optics, including the wires that comprise a system bus coupled to a processor of a computer. Common forms of computer-readable media include, for example, a floppy disk, a flexible disk, hard disk, magnetic tape, any other magnetic medium, a CD-ROM, DVD, any other optical medium, punch cards, paper tape, any other physical medium with patterns of holes, a RAM, a PROM, an EPROM, a FLASH-EEPROM, any other memory chip or cartridge, or any other medium from which a computer can read.

Databases, data repositories or other data stores described herein may include various kinds of mechanisms for storing, accessing, and retrieving various kinds of data, including a hierarchical database, a set of files in a file system, an application database in a proprietary format, a relational database management system (RDBMS), etc. Each such data store is generally included within a computing device employing a computer operating system such as one of those mentioned above, and are accessed via a network in any one or more of a variety of manners. A file system may be accessible from a computer operating system, and may include files stored in various formats. An RDBMS generally employs the Structured Query Language (SQL) in addition to a language for creating, storing, editing, and executing stored procedures, such as the PL/SQL language mentioned above.

In some examples, system elements may be implemented as computer-readable instructions (e.g., software) on one or more computing devices (e.g., servers, personal computers, etc.), stored on computer readable media associated therewith (e.g., disks, memories, etc.). A computer program product may comprise such instructions stored on computer readable media for carrying out the functions described herein.

With regard to the processes, systems, methods, heuristics, etc. described herein, it should be understood that, although the steps of such processes, etc. have been described as occurring according to a certain ordered sequence, such processes could be practiced with the described steps performed in an order other than the order described herein. It further should be understood that certain steps could be performed simultaneously, that other steps could be added, or that certain steps described herein could be omitted. In other words, the descriptions of processes herein are provided for the purpose of illustrating certain embodiments and should in no way be construed so as to limit the claims.

Accordingly, it is to be understood that the above description is intended to be illustrative and not restrictive. Many embodiments and applications other than the examples provided would be apparent upon reading the above description. The scope should be determined, not with reference to the above description, but should instead be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled. It is anticipated and intended that future developments will occur in the technologies discussed herein, and that the disclosed systems and methods will be incorporated into such future embodiments. In sum, it should be understood that the application is capable of modification and variation.

All terms used in the claims are intended to be given their ordinary meanings as understood by those knowledgeable in the technologies described herein unless an explicit indication to the contrary is made herein. In particular, use of the singular articles such as "a," "the," "said," etc. should be read to recite one or more of the indicated elements unless a claim recites an explicit limitation to the contrary.

The Abstract is provided to allow the reader to quickly ascertain the nature of the technical disclosure. It is submitted with the understanding that it will not be used to interpret or limit the scope or meaning of the claims. In addition, in the foregoing Detailed Description, it can be seen that various features are grouped together in various embodiments for the purpose of streamlining the disclosure. This method of disclosure is not to be interpreted as reflecting an intention that the claimed embodiments require more features than are expressly recited in each claim. Rather, as the following claims reflect, inventive subject matter lies in less than all features of a single disclosed embodiment. Thus, the following claims are hereby incorporated into the Detailed Description, with each claim standing on its own as a separately claimed subject matter.

What is claimed is:

1. A system, comprising:

a gateway computer, programmed to:

distribute an encryption key, in a unicast mode, to a plurality of satellite terminals;

receive data from a remote computer; and

multicast the received remote computer data to the plurality of satellite terminals by:

encrypting the received remote computer data with the encryption key; and

multicasting the remote computer data encrypted with the encryption key to a plurality of terminals,

wherein each of the plurality of satellite terminals includes:

a terrestrial communication interface;

a satellite communication interface, for satellite communication with the gateway computer via a satellite link, wherein the terrestrial and satellite communication interfaces are configured to communicate traffic data; and

a satellite terminal computer communicatively linked to the terrestrial and satellite communication interfaces, wherein the satellite terminal computer executes instructions comprising, to:

determine that the traffic data, communicated via the terrestrial communication interface, exceeds a threshold; and

based on the determination, route at least a portion of traffic data via the satellite communication interface in accordance with a predetermined traffic data load-balancing scheme.

2. The system of claim **1**, wherein the computer is further programmed to:

determine a terrestrial link quantifier and a satellite link quantifier; and

select at least one of the terrestrial communication interface and the satellite communication interface further based on the terrestrial link quantifier and the satellite link quantifier.

3. The system of claim **1**, wherein the computer is further programmed to:

determine a first score of the traffic data based on at least one of a data throughput, a data type quantifier, and a terrestrial link quantifier; and

route at least the portion of traffic data via the satellite communication interface upon determining that the first score of the traffic data exceeds the threshold.

4. The system of claim **3**, wherein the computer is further programmed to determine the data type quantifier based at least on one of the data throughput, a data volume, and a data priority.

5. The system of claim **4**, wherein the computer is further programmed to determine the data priority based at least in part on a latency threshold of the traffic data.

6. The system of claim **1**, wherein the computer is further programmed to:

receive, via a local communication network, a plurality of data packets from a plurality of IoT devices;

generate an aggregated data packet including the received plurality of data packets; and

transmit the aggregated data packet via the satellite communication interface to a remote computer.

7. The system of claim **6**, wherein the computer is further programmed to:

determine a first score of the plurality of data packets for communicating via the terrestrial communication interface;

determine a second score of the aggregated data packet for communicating via the satellite communication interface; and

transmit the aggregated data packet via the satellite communication interface upon determining that first score exceeds the second score.

8. The system of claim **1**, wherein the computer is further programmed to communicate with one or more IoT devices, via an IoT interface, wherein the traffic data includes data received from or sent to the one or more IoT devices.

9. The system of claim **1**, further comprising an IoT device comprising a second computer, programmed to:

receive the multicast including the encryption key and the encrypted remote computer data;

decrypt the remote computer data based on the encryption key; and

actuate an actuator based on the decrypted remote computer data.

10. The system of claim **1**, wherein the gateway computer is further programmed to:

receive, via a satellite uplink, a reception quality status including a link condition; and

adjust, based on the received quality status, at least one of multicast parameters including a data throughput, a transmission power, and a transmission spectral efficiency.

11. The system of claim **10**, wherein the gateway computer is further programmed to:

divide, based on the received quality status, the plurality of terminals into a first group with a first set of multicast parameters and a second group with a second set of multicast parameters;

multicast the remote computer data based on the first set of multicast parameters via a first downlink; and

multicast the remote computer data based on the second set of multicast parameters via a second downlink.

12. The system of claim **1**, wherein the gateway computer is further programmed to distribute the encryption key to the plurality of satellite terminals in unicast mode by transmitting data including the encryption key to each of the plurality of satellite terminals, wherein data transmitted to each of the satellite terminals, in unicast mode, is encrypted with a terminal-specific encryption key.

13. A method, comprising:

distributing an encryption key, from a satellite gateway computer, in a unicast mode, to a plurality of satellite terminals;

receiving data from a remote computer;

multicasting the received remote computer data to the plurality of satellite terminals by:

encrypting the received remote computer data with the encryption key; and

multicasting the remote computer data encrypted with the encryption key to a plurality of terminals,

determining, in a satellite terminal, that traffic data of the terminal, communicated via a terrestrial communication interface of the terminal, exceeds a threshold; and

based on the determination, routing at least a portion of traffic data via a satellite communication interface of the terminal in accordance with a predetermined traffic data load-balancing scheme, wherein the terrestrial and satellite communication interfaces are configured to communicate traffic data.

14. The method of claim **13**, further comprising:

determining a terrestrial link quantifier and a satellite link quantifier; and

selecting at least one of the terrestrial communication interface and the satellite communication interface further based on the terrestrial link quantifier and the satellite link quantifier.

15. The method of claim **13**, further comprising:

determining a score of the traffic data based on at least one of a data throughput, a data type quantifier, and a terrestrial link quantifier; and

routing at least the portion of traffic data via the satellite communication interface upon determining that the score of the traffic data exceeds the threshold.

16. The method of claim **15**, further comprising determining the data type quantifier based at least on one of the data throughput, a data volume, and a data priority.

17. The method of claim **16**, further comprising determining the data priority based at least in part on a latency threshold of the traffic data.

18. A system, comprising:

a terminal including:

a terrestrial communication interface;

a satellite communication interface, wherein the terrestrial and satellite communication interfaces are configured to communicate traffic data; and a computer communicatively linked to the terrestrial and satellite communication interfaces,

wherein the computer executes instructions comprising, to:

determine that the traffic data, communicated via the terrestrial communication interface, exceeds a threshold; and

based on the determination, route at least a portion of traffic data via the satellite communication interface in accordance with a predetermined traffic data load-balancing scheme;

a gateway computer, programmed to:

receive data from a remote computer;

multicast the received remote computer data to a plurality of terminals, wherein the plurality of terminals communicates with IoT devices via one or more local communication network;

distribute an encryption key, in a unicast mode, to a plurality of second computers;

encrypt the received remote computer data with the encryption key; and

multicast the received remote computer data to a plurality of terminals; and

an IoT device comprising one of the plurality of second computers, programmed to:

receive the distributed key and the encrypted multicast data;

decrypt the multicast data based on the distributed key; and

actuate an actuator based on the decrypted data.

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